The digital revolution of hydropower in Latin American countries

Energy Division/ Infrastructure
and Energy Sector

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THE DIGITAL REVOLUTION OF HYDROPOWER

IN LATIN AMERICAN COUNTRIES

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Arturo Alarcón

Digital technologies have been present in the electric sector since its inception, given its nature of high technological level. Supervisory Control and Data Acquisition systems (known as SCADA), have been common in power systems for decades. Likewise, the use of advanced computer models for planning, sizing and simulation of generation, transmission and distribution systems is a business-as-usual application of technology in the sector.

Nonetheless, despite the strong familiarity of this sector with “digitalization”, the new wave of innovation, called Industrial Revolution 4.0, promises to bring profound changes to the way we build, design, operate and maintain our electrical systems, going far beyond the simple use of computer models and isolated SCADA systems. There are four main factors that changed in recent years: (i) the increase in computing capacity of the commercial processors (which went from less than 1 MHz in the 1970s to more than 4 GHz in 2019); (ii) the reduction of the cost of these processors; (iii) the increase in the capacity of communication networks, which allow for the processors and digital systems to be combined with each other, even remotely, multiplying exponentially the processing capacity; and (iv) the development of new algorithms for the analysis and management of data (including what is now called “Big Data” and “artificial intelligence”). These factors

created the ideal conditions for an exponential growth in the number and capacity of digitalization applications, which in turn provides immense possibilities in the electricity sector.

The new possibilities are not trivial for Latin-American and the Caribbean (LAC), particularly considering the hydroelectric sector, which provides about half of the electricity of this region and is the main source of generation in many countries. Many of these hydropower plants were installed several decades ago, and digitization will be an essential element to rehabilitate, modernize, and maintain them as part of a sustainable and secure electricity matrix. However, the subject is still not widely explored and exploited in the region. That is why at the beginning of 2019 the IDB commissioned this technical note to Poyry, in order to present a current and useful review and discussion about digitalization in the Latin American hydropower sector.

The note starts with a description of where is LAC in terms of digitalization in general. Then, it explores the relevance of digitalization for the hydropower industry in the region. Four case studies are presented, which enable to explore from first-hand experiences how digitalization is being applied in the sector, and to identify some of the key benefits. This analysis permits also to explore the key barriers for digitalization, and to present some recommendations for its further development on the region. Finally, some key conclusions are presented.

It is worth mentioning that the note is not intended to be all-encompassing and to include all aspects related to digitalization, or to serve as a technical guide for project developers. Specifically, the main objective of the note is to present a current overview of digitalization of hydropower in LAC, with an overview of some technologies, with real case studies, in order to create a discussion about the key benefits that digitalization can bring to hydroelectric sector in the region, and to identify some key barriers that should be addressed by regulatory agencies and policy makers.

This is a topic that is advancing rapidly, and some of the technologies treated in this note might advance rapidly with new developments and applications. Nonetheless, the general discussion on how digitalization can be implemented, and the identification of the barriers that need to be addresses, might be relevant for the next coming years.

Finally, there is a key point that must not be forgotten: The human element is the key. We cannot write and speak about digital solutions without thinking about people, because technology will only help people make better decisions. Digitalization proposes not only the adoption of new technologies, but the need to modernize the organizational structures. The ability of our countries and organizations to adapt and, even more, to be proactive in this new era will be essential to guarantee they are not left behind.

EXECUTIVE SUMMARY

Digitalization is transforming economies around the world and already impacts the economic growth and has a direct positive impact, contributing to an increase of the GDP in the order of 20 to 40%[1] . The huge potential of digitalization also will benefit the energy sector in terms of increased productivity and efficiency and reduced costs in operation and maintenance. Broadly speaking, 'Digitalization' can be defined as the use of digital technologies (sensors, connected devices, network equipment, infrastructure and systems) to increase efficiency or to change the underlying business model by creating new sources of revenue.

LAC countries are positioned at an intermediate level respect to other world regions in terms of digital development. Nevertheless, according to a recent study, nearly half of the 24 LAC studied markets are experiencing a digital growth spurt in the last years, but not all the countries are growing digitally at the same rate. Countries like Chile, Costa Rica, Uruguay, Mexico and Colombia are representing the leaders, with a higher "Digital Evolution Index" (explained later in this document), in both digital evolution and in their rate of progress i.e, digital momentum. On the contrary, El Salvador, Barbados and Venezuela still are slow moving or declining due to the political and social environment. Missing infrastructure, unavailable technologies, reduced public budgets, increased bureaucracy as well as unexperienced end-users due to poor or no internet connection are main factors for the slow pace in digital developments in the LAC economies compared to other regions on the globe.

In the power sector, digitalization adds undeniable value to safety and environmental objectives, with indirect impact on the financial benefits regarding the reduced/avoided costs. On the commercial side, the immediate benefits of digitalization can be summarized as reducing operation and maintenance (O&M) costs; improving power plant and network efficiency; being able to coordinate future maintenance with the future value of energy and weather and hydrological data; reducing unplanned outages and downtime; and extending the operational lifetime of assets – hence maximizing the profits from a power plant investment.

When looking at hydropower in LAC, nowadays it represents more than half of electrical energy production in LAC. In 2017, the total installed capacity of hydropower reached almost 187 GW which represents 45% of the total installed capacity in the region. In most LAC countries private energy generators, which are mainly linked to European and US companies and representing the major part of the electricity markets, are implementing the lessons learned in digitalization in hydropower from their home countries in the local markets with the back-up of local and foreign capital. For contemporary facilities, SCADA systems represent a standard design requirement allowing the implementation of further future digital technologies and communication with each part of the plant. Centralized operation from a single operation control center is one of the main goals for digitalization of hydropower in LAC, taking into consideration the upgrade and modernization of older plants.

This was also confirmed by Poyry's client interviews undertaken with hydropower generators in Chile, Mexico and Peru, where digital initiatives are already implemented but with the major focus on centralized operation and improved O&M activities. As an outcome, it shall be noted, that besides barriers coming from rigid regulations, human capital and insufficient number of educated staff in the field of digitalization is not seen as an obstacle to further evolve in the digital development. Nonetheless, in some case automation might cause the reduction of personnel in some plants, if this personel is not re-trained to perform other taks.

1. See references in section 1

Maximizing the benefits from digitalization requires an elimination (or at least mitigating) of different types of barriers at national level, i.e. ensuring there is sufficient infrastructure; an efficient market design and a state-of-the art education system which can bring up professionals equipped with required skills, the elimination of barriers at company level and ensuring digital readiness through an efficient change management as well as regulatory incentives.

As a summary, the following can be concluded for the digitalization in hydropower in LAC region:

- Digitalization development in LAC countries is not homogenous and it is still behind Europe and US. The leading countries in the region in this regard are Chile, Colombia, Argentina, Brazil and Costa Rica.

- Considering infrastructure, human capital and legal framework as main factors for digital development, Chile is leading the way to digitalization. Most countries within LAC region will need to accelerate their efforts to stay ahead of the fast-moving digital wave and its benefits.

- The LAC region shows low levels of investment on innovation to promote digitalization at public and private levels. Due to limited budgets and the tendency towards bureaucratic processes at all state levels, digitalization in the private sector is growing faster than the public sector.

- Hydropower will continue to play an important role in energy generation in the next decades in LAC region. Therefore, adoption of digital technologies will bring new opportunities for its improvement in terms of decision-making processes to optimize the cost of operation, prevent forced outages and to bring enhanced technologies to refurbish and modernize old plants.

- Particularly, hydropower already is an enabler for the deployment of non-conventional renewable generation, as it provides flexibility and storage capabilities. Digitalization of older hydropower plants will be necessary to improve the operation of hydropower with other variable technologies, improving the system's security and efficiency.

- The range of application of digital technologies in the hydropower sector spans the whole hydropower plant lifecycle (planning & design, construction and the operation & maintenance) to meet high level objectives (safety, sustainability and commercial)

- In general, in the LAC region, the main issue for hydropower digitalization is centralized operation through SCADA system. However, there are already different hydropower operators in the LAC energy sector, which besides the implementation of SCADA systems also are implementing different digitalization initiatives related to operational safety, digital tools in the b2c sector as well as digital initiatives improving internal processes (e.g. in legal & procurement departments) in order to stay competitive in the changing energy market.

1. DIGITALIZATION

Digitalization is transforming economies around the world and already impacts the economic growth. Among various publications a study[2] mentions that a 10% increase in digitalization would produce an increase in the GDP from 0.50% to 0.62% moving the studied 150 countries from a constrained to an advanced level of digital development. The same study showed that already from 2007 to 2010 a GDP growth of 45% was observed in these investigated countries thanks to digitalization. For Mexico another study[3] foresees a GDP growth up to 15 percent in 2025 with respect to 2018 if the country achieves a good to very good digital maturity rating[4]. The huge potential of digitalization also will benefit the energy sector in terms of increased productivity and efficiency and reduced costs in operation and maintenance. The International Energy Agency (IEA)[5] estimates that digitalization within the power sector has the potential to save approximately USD 80 billion per year, or about 5% of the total annual power generation costs around the world taking into consideration the current system design and assuming enhanced deployment of available digital technologies to all power plants and network infrastructure worldwide. Digitalization also plays an important role in achieving the Sustainable Development Goals (SDGs), especially SDG7 which is "Affordable and Clean Energy"[6]. In general, and resuming briefly the current literature, digitalization will definitely play a major role in the upcoming years all over the globe and will have a positive economic impact in almost all business sectors – among them the energy business.

2. Maximizing the Impact of Digitization (Booz & Company,2012)

3. How Mexico can become Latin America's digital-government powerhouse (McKinsey & Company, 2018)

4. To assess the digital maturity of 151 countries, McKinsey used 26 publicly available indicators (such as those from the International Telecommunication Union, United Nations, and World Bank) to analyze four key dimensions of a government's digital strategy: digital foundations, government, economy, and society. Cuts between the different levels of the Digital Maturity Index were determined according to the distribution of the results of all "high income" and "upper middle income" countries (eg, Colombia), according to the World Bank classification. The cut of "very good" corresponds to scores between 1 and 2 standard deviations above the simple average (91>x>74), "good" to scores between the simple average and 1 standard deviation above the simple average (74>x>57), "acceptable" to scores between the simple average and 1 standard deviation below the simple average (57>x>40), and "poor" to scores of 1 standard deviation below the simple average (x<40). The index excluded 2 subdimensions of the framework (informed citizens and use of advanced analytics in government) due to a lack of data to measure them.

5. Digitalization & Energy, International Energy Agency (IEA), 2018

6. The impact of Digital Infrastructura on the Sustainable Development Goals (IDB, 2019)

1.1

WHAT IS DIGITALIZATION?

Broadly speaking, 'Digitalization' can be defined as the use of digital technologies (sensors, connected devices, network equipment, infrastructure and systems) to reduce costs or to change the underlying business model by creating new sources of revenue. These technologies can be grouped into three categories as shown in Figure 1:

- Access to new sources of data and communications;
- Decision-support systems based on improved analysis and visualization tools; and
- Automation and control.

Figure 1: What is 'digitalization'?

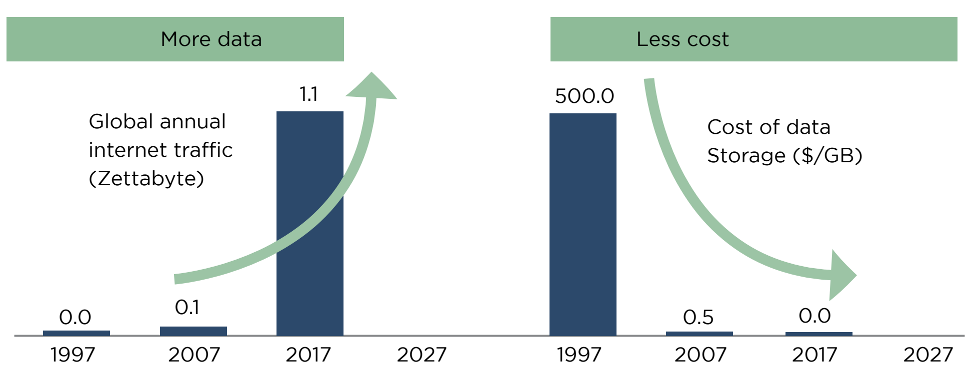
Source: Pöyry Management Consulting

Many of these 'digital technologies' mentioned above are not new. Most of today's workforce started employment in the age of desktop computers, and digital information and processing has been mainstream for several decades. The next wave of digitalization is differentiated from the business-as-usual use of digital technologies to date by the explosion of technology breakthroughs and associated data, driven by collapsing costs of data storage, sensor and communications technologies, as well as increased processing power and new approaches of data analysis and management such as machine learning, deep learning or artificial intelligence (AI). This AI enables digitalization projects to evolve from simply automating laborious tasks to enabling advanced decision making, which can surpass human analysis and control, which ultimately leads to new business models and new sources of value.

Figure 2 illustrates the accelerating change using some everyday examples; global annual internet traffic surpassed the exabyte threshold in 2001 and passed the zettabyte threshold by 2017[7], whilst over the same period the cost of hard drives has halved roughly every 14 months. In the last five years, global mobile broadband subscriptions increased threefold and surpassed 4 billion active subscriptions. There are now more mobile phone subscriptions (8 billion) than people in the world. The exponentiality of the internet is now moving from people to things (e.g. sensors, widgets, cameras and platforms), connected through algorithms, people, and other things. These developments have enabled digitalization projects to evolve from simply automating laborious tasks to enabling advanced decision making and control which ultimately leads to new business models and new sources of value.

Figure 2: Digitalization is being driven by an explosion of new technologies capable of generating more data at ever declining unit costs

Source: Pöyry Management Consulting using IEA data for internet traffic and Internet Archive/Blackbaze for hard disc drive costs.



7. Digitalization and Energy 2017, IEA.

Figure 3: Four Drivers of Digital Evolution

Source: Fletcher School, Tufts University July 2017 "Digital Planet 2017, How Competitiveness and Trust in Digital Economies vary across the World"

SUPPLY CONDITIONS

Access Infrastructure

Communications sophistication and coverage; secunty

Transaction Infrastructure

Access to financial institutions; electronic payment options

Fulfillment Infrastructure

Quality of transportation infrastructure; logistics performance

DEMAND CONDITIONS

Consumer Capacity to Engage

Consumer ability and willingness to spend; gender digital divide

Digital Payment Uptake

Degree of financia ! inclusion and use of digital money

Digital Uptake

Device prevalence and density: technology, internet. and mobile connection uptake: digital consumption

INSTITUTIONAL ENVIRONMENT

Institutions and the Business Environment

The legal environment including efficiency in settling disputes. IP and investor protections: and Bureaucracy

Institutions and the Digital Ecosystem

Government uptake and use of ICT and digital technology; telecom competition

Institutional Effectiveness and Trust

Transparency: rule of law: regulatory quality

INNOVATION AND CHANGE

Inputs

Financing options and opportunity: start-up capacity; ability to attract and retain talent

Process

Sophistication of business practíces: R&D

Output

Depth of mobile engagement; reach of innovation; use of social networks and digital entertainment

According to the investigation from the Fletcher School[8], basically four drivers were defined that govern a country's digitalization: Supply Conditions, Demand Conditions, Institutional Environment, and Innovation and Change with the aim to calculate a Digital Evolution Index (DEI) to gain a comprehensive view of digital readiness and competitiveness of countries in the LAC region. While the key elements of the four drivers are listed in Figure 3, the analysis framework for the DEI is discussed extensively in the source document, results of this survey are shown in Figure 4.

1.2

DIGITALIZATION IN LATIN AMERICA AND THE CARIBBEAN (LAC)

According to the Development Bank of Latin America (CAF) observatory index of digital ecosystem development reported in 2015, LAC countries with an average development index of 45.47 are positioned at an intermediate level respect to other world regions – e.g. US and Canada reached 74.4 on average[9] (see Annex I for a detailed explanation of the index).

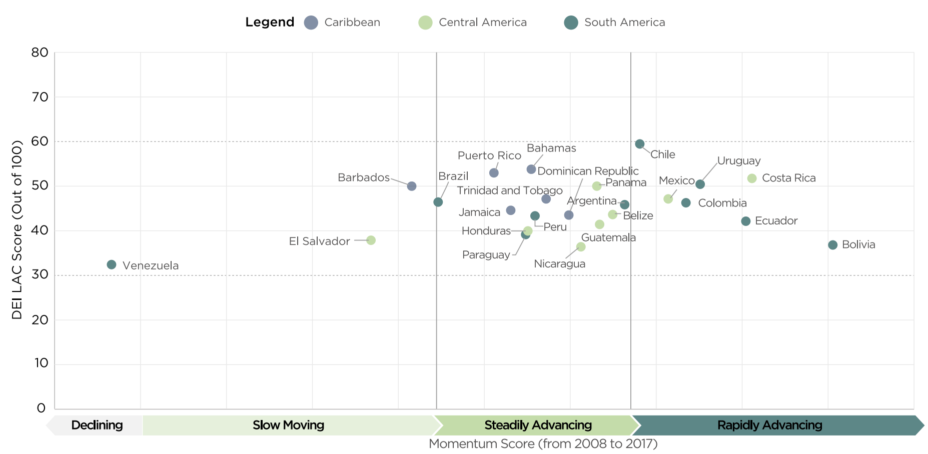
8. Fletcher School, Tufts University July 2017 "Digital Planet 2017, How Competitiveness and Trust in Digital Economies vary across the World"

9. Hacia la transformación digital de América Latina y el Caribe: El Observatorio CAF del Ecosistema Digital (CAF, 2017)

Surveys and recent publications talking about the digital status in the LAC region are in general consistent within their results although the indexes applied to measure the evolution and development of digitalization are calculated in different ways, which might not be comparable when going in further detail and discussing a special business sector. A recent study done by the Fletcher School, based on 99 unique indicators over a ten-year period (2008-2017), showed that nearly half of the 24 LAC countries studied are experiencing a digital growth spurt. Nevertheless, not all the countries are growing digitally at the same rate. Countries like Chile, Costa Rica, Uruguay, Mexico and Colombia are representing the leaders, with a higher "Digital Evolution Index", in both digital evolution and in their rate of progress i.e, digital momentum[10]. Only Venezuela, El Salvador and Barbados still are slow moving or declining due to the political and social environment (see Figure 3). These recent results also confirm the outcomes from CAF[11] from 2015, which stated that the leading countries in the context of digitalization are Chile, Colombia, Argentina, Brazil and Costa Rica while Peru, Paraguay and Bolivia were among the less advanced countries with limited digitalization development in 2015. Hence, most of the rather limited countries in 2015 showed further progress in the last 3 years and changed from limited to steadily advancing. This shows that the evolution in digitalization is rather fast and results might change rapidly from year to year. These drivers are also valid when talking about the energy markets.

Figure 4: The Digital Evolution Index: Latin America & Caribbean Edition (DEI LAC)

Source: Digital Evolution Index: Latin America & Caribbean Edition, The Fletcher School, Tuft University, November 2018



Among the main factors for digitalization or digital development are infrastructure, human capital and legal framework.

With respect to infrastructure, the most important variable is the available connection to the Internet (connectivity). In this regard Chile is far leading the implementation of high-speed internet connections, which is underpinning its good performance in digital evolution[12].

Apart from the basic physical environment, human capital, which refers to the skill of workers to drive forward digital transformation, innovation, patents and start-ups, in turn requiring adequate education and training plays an important role in the context of digital evolution of the energy sector. In terms of education, LAC has had a signi-

10. Digital Evolution Index: Latin America & Caribbean Edition, The Fletcher School, Tuft University, Nov. 2018

11. Hacia la transformación digital de América Latina y el Caribe: El Observatorio CAF del Ecosistema Digital (CAF, 2017)

12. DataReportal - https://datareportal.com/reports/digital-2019-global-digital-overview

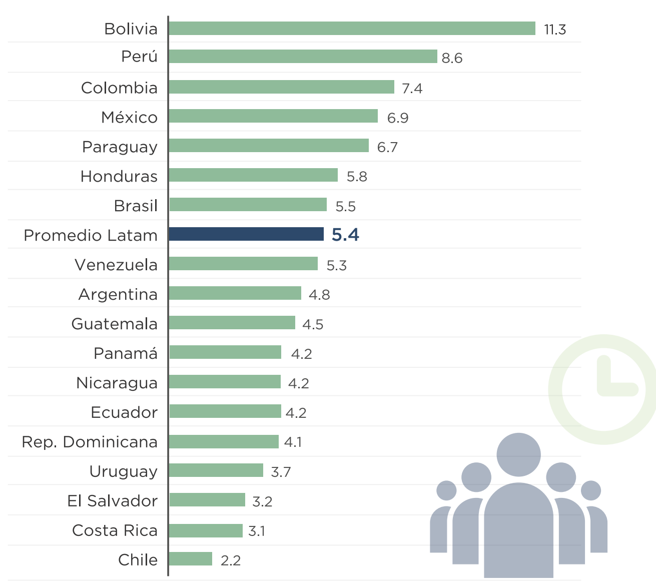
ficant improvement from 2004 to 2015 with a continuously growing number of university students in digital areas and increasing number of computers in schools per student[13] . However, in terms of the percentage of GDP spent on R&D in LAC versus OECD, LAC lies far behind with 0.69%, compared to 2.17 % in the Organization for Economic Cooperation and Development (OECD) countries in 2015. Regarding careers that promote digital transformation like engineering, science and construction in LAC, only 943 of a total of 1,000,000 habitants are studying in these fields; whereas the numbers for Asia Pacific and OECD countries are almost three (3) times higher. Among LAC countries, only Chile and Colombia (almost) reach this level

The institutional and regulatory frameworks are essential to facilitate the development of the digital industries as well as the promotion of connectivity. In this regard, Chile should be considered as a leading example in the LAC region as new innovative frameworks were put in place in the last year which opens various possibilities for digital industry. In most of the other LAC regions rigid frameworks are in place with limited possibilities, to react on the fast moving digital world, e.g. tedious procedures for approving changes or modernization, which take rather long time compared with the private sector and thus hinder the implementation of digital applications.

As it can be seen from Figure 5, Chile as the leader in digitalization in LAC, is also outstanding when talking about agile procedures within the authorities. This is because several processes are already working via internet platforms and mobile apps; as such development has been explicitly pushed by corresponding laws (Digitalization law and Digital transformation law). Furthermore, governmental internal processes have already been incorporated in a digital environment, too. All these efforts lead to a more agile response and shorter reaction times

Figure 5: Average Hours spent on processes with authorities

Source: IADB - https://cloud.mail.iadb.org/tramites#el-problema-con-los-tramites



In terms of public and private investment to promote innovation, local production of innovation and economic development in the LAC region shows low levels[14]. In general, digitalization in the private sector is growing faster than that in public sector due to the limited budget and the tendency towards bureaucratic processes at all state levels[15] .

13. Capital humano para la transformación digital en América Latina (Katz, Raül L; 2018)

14. Hacia la transformación digital de América Latina y el Caribe: El Observatorio CAF del Ecosistema Digital (CAF, 2017)

15. The economic contribution of broadband, digitization and ICT regulation, ITU 2018

1.3

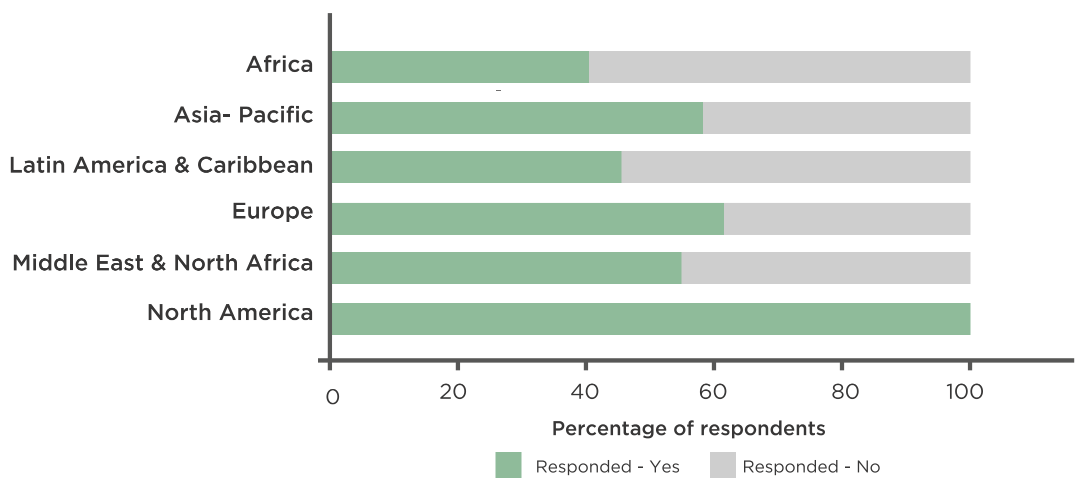
DIGITALIZATION IN THE ENERGY MARKETS OF LAC

In the digitalization context, the level of development of a state and society in terms of economics, digital readiness and regulatory boundary conditions plays a significant role in encouraging the digitalization of its industries. In any case the application of digital technologies in the energy business is looking for higher cost efficiency, increased earnings, increased safety, higher resource efficiency as well as overall value chain optimization up to the end customer. This is also valid for the LAC region but struggles with the rather slow developments stated in the previous section.

Missing infrastructure, unavailable technologies, reduced public budgets, increased bureaucracy as well as unexperienced end-users due to poor or no internet connection are main factors for the slow pace in digital developments in the LAC energy markets compared to other regions on the globe. In general, the cost of digital technologies has not been identified as a barrier, although the cost-effectiveness of these technologies is seen as a key aspect for their implementation.

A measure of good practices and transparency is the ability of the utilities (or the government) to share real-time data on energy demand, supply and outages. The United Nations E-Government Survey 2018 (Figure 6) shows that LAC is considerably behind Europe and North America in terms of sharing real-time data on power outages, as an indicator of the level of connectivity within the sector.

Figure 6: Percentage of countries with-government sites
that share updates and information on electricity or power outages
Source: UNITED NATIONS E-GOVERNMENT SURVEY 2018

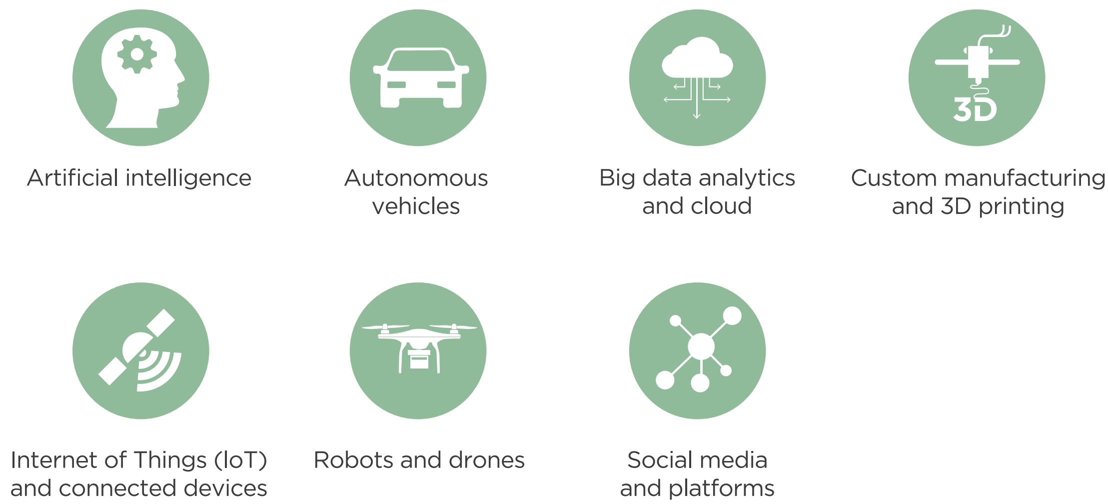


Sample size: North America (n=2), Latin America & Caribbean (n=33), Europe (n=42),
Asia-Pacific (n=48), Middle East & Africa (n=20) & Africa (n=47)

16. McKinsey , 2016 "The digital utility: New opportunities and challenges"

According to the outcome from the "Digital Transformation Initiative" presented at the World Economic Forum, there are basically seven main key technologies that are transforming and have the most important impacts on the energy industry, as it is shown in Figure 5. Most of these technologies are applied to asset life cycle management, grid optimization and aggregation and integrated customer services. By applying these new digital technologies, the digital utility of the future will capture opportunities all along the value chain (see Figure 6)[16] . Nevertheless, the successful implementation will depend on the expansion of the infrastructure (broadband communication, end user ability, etc.) as well as the participation of the end users to take advantage of these new services.

Figure 7: Most important digital technologies impacting the energy industry
Source: Pöyry Management Consulting



Despite the rather slow progress in digital development as stated in the previous section there are several positive examples of digital initiatives in LAC:

- In Peru, the private, non-profit with public laws owned grid regulator called the Economic Operation Committee of the National Interconnected System (COES) developed a mobile phone application sharing real time data on demand, generation pricing as well as failures in the system in a full transparent way.

- Similar information platforms are provided by the National Grid Operator CEN in Chile, as well.

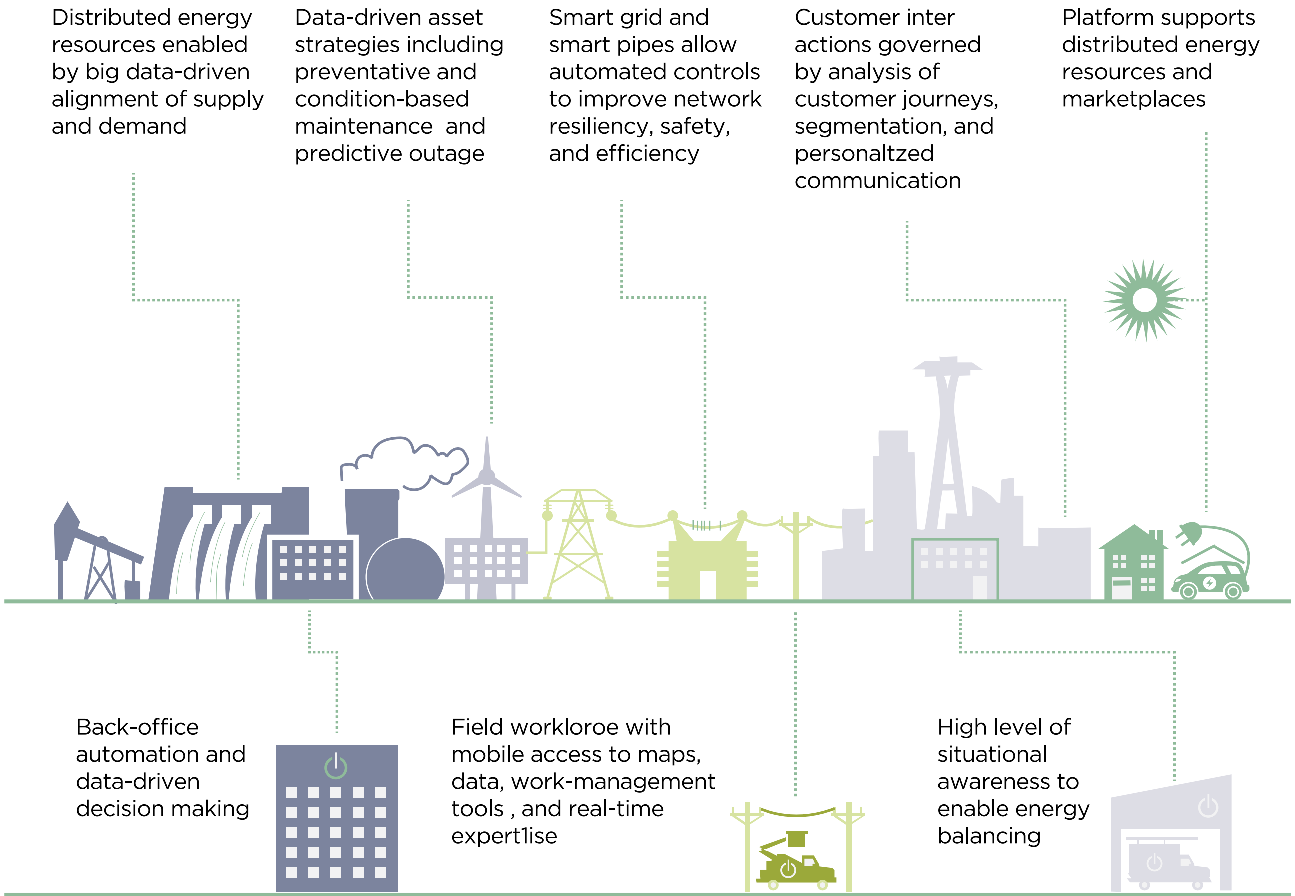
- Several digital initiatives are taking place in the LAC region mostly in the context of smart metering, energy efficiency as well as Smart Cities (see Annex IV), representing positive examples for further investments in infrastructure, and thus allowing further developments in the electricity generation market.

- Furthermore, and according to Pöyry Energy Business Group experience, more than three-fourths of the LAC energy companies are aware about the growing trend towards digitalization in the hydropower sector and are already implementing digital solutions in their daily business.

Nevertheless, it has to be noticed that, despite these positive digital initiatives and implementations at the generation side, incorporation of end-users through smart-phone applications, which allows them to select their energy mix or monitor their consumption via smart metering are not foreseen to be available or implemented during the upcoming years due to the lack of appropriate infrastructure.

Figure 8: Digital Utility of the future

Source: McKinsey, 2016 “The digital utility: New opportunities and challenges”



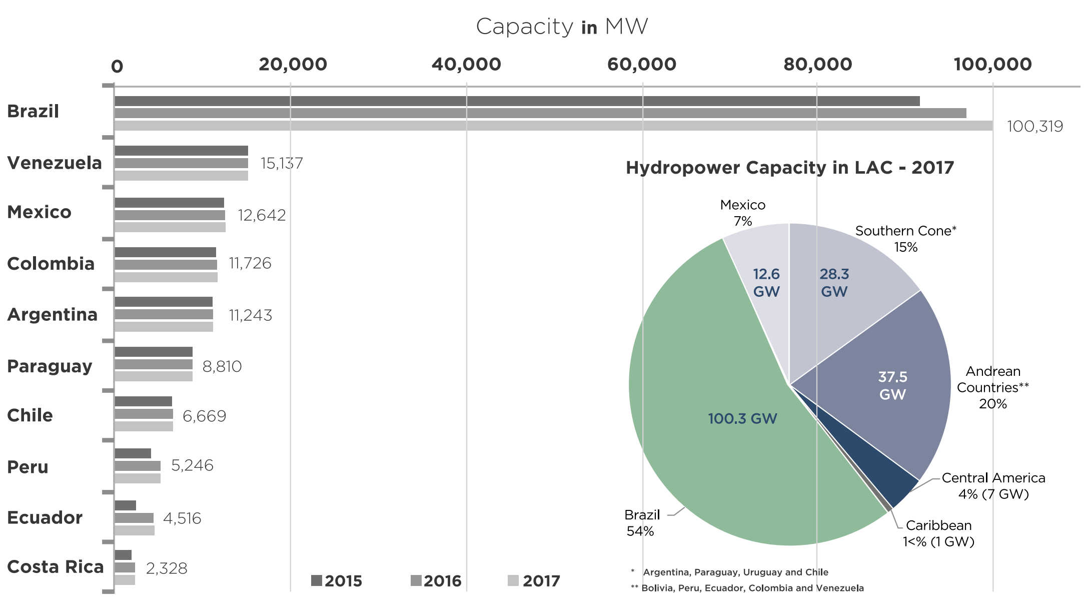
2. HYDROPOWER IN LAC

According to a survey from the Latin American Organization of Energy (OLADE) among main stakeholders in the energy sector across LAC countries, hydropower will certainly play a leading role in energy generation in the next 20 years[17] in LAC region.

Based on the latest review of the energy database from OLADE, generation from hydropower represents more than the half of electrical energy production in Latin America and the Caribbean (LAC). In 2017, the total installed capacity of hydropower reached about 186 GW which represents 45% of the total installed capacity in the region. According to the latest report of IHA[18], a total installed capacity of about 190.7 GW is reported, meaning, that in 2018 almost 5 GW of new hydropower facilities were installed in the region.

Figure 9: Total Hydropower Capacity in LAC – Top 10 Countries

Source: Pöyry Energy Business Group using database from OLADE



17. Barómetro De La Energía De América Latina Y El Caribe 2018 Las Perspectivas Del Desarrollo Del Sector Energético En La Región Olade 2018

18. IHA – hydropower status report 2019 - sector trends and insights

Hydropower development in Latin America began at the end of the 19th century, initially in Brazil (1883), Guatemala (1884) and Costa Rica (1884) as pioneering countries, then continuing in the other countries, which installed their first hydropower plants between 1890 and 1900. At the beginning, hydropower was linked to mining development, particularly in Mexico, Chile, Peru and Bolivia. In the beginning of hydropower development, most of the capital came from foreign companies. However, between 1930 and 1970, state participation in financing and development increased significantly with the creation of state owned companies across the region such as CFE (Mexico), ENDESA (Chile), AyE (Argentina), EPM (Colombia), ELETROBRAS (Brazil), ENDE (Bolivia), ELECTROPERU (Peru), among others. During the 1970s and 80s, hydropower development in LAC reached its peak period, when hydropower capacity was increased by 5 times with the installation of more than 70 GW in only 20 years. In the 90s, and the 2000s the development has continued with the installation of additional 60 GW. Despite the decline in the pace of hydropower investments in the last decade, mainly due to the increase in gas power plant investments, it is expected that the hydropower generation will continue playing an important role to meet the growing demand in LAC. Within this context it is important to note that, only 25% of the total hydropower potential is currently developed and there are still more than 500 GW of technical feasible potential to be exploited, mainly in Brazil and the Andean countries (Peru, Colombia, Bolivia, Venezuela and Ecuador)[20].

As shown in Figure 7 above, Brazil is the leading country in hydropower development in terms of both the total capacity (i.e. .100.3 GW installed capacity in 2017 and 104 GW in 2018) and the annual increase in capacity (i.e. 5.3 GW in 2016, 3.4 GW in 2017 and 3.8 GW in 2018).

In Brazil, the share of renewable (wind, solar and small hydro with less than 50 MW) energy has increased in the generation mix since the energy reform in 2012. Furthermore, participation of private investors (Engie, Enel and SPIC) in the auctions of four hydro plants in 2017 shows the ongoing trend to liberalism and modernization of the sector which began under the previous government[21] .

In Colombia, generation from hydropower increased to 86% of total generation in 2017, exceeding the 70% average of the previous years. The World Economic Forum ranked Colombia as 8th in the Global Energy Architecture Performance Index (EAPI), which measures countries' performance to deliver secure, affordable and sustainable energy, being the first non-European country in the top ten[19].

In Chile, local energy resources are limited. The country depends mainly on hydrology and fuel imports to meet energy demand. After the 'gas crisis' with Argentina, the predominant primary source for power generation was hydro until 2010. Between 2010 and 2013, there was a steep increase in coal fired generation, changing the Chilean energy mix. More recently, there has been a considerable increase in non-conventional renewable energy (compared to 2016 levels, wind and solar generation increased by 56% and 53%, respectively, in 2017). While hydropower expansion has been affected by recent droughts, stakeholder conflicts and already high deployment; the potential for solar and wind power in Chile is vast and investors as well as the Chilean government have begun to explore it. The Ministry of Energy has approved a roadmap for 2050 where the goal of renewable energy in the energy matrix shall reach 70%. Therefore, for future central scenarios up to 2050, most of the generation is ultimately expected to come from renewable energy. Furthermore, fossil fuels and in particular coal shall be phased out completely by 2030. Another challenge in the energy landscape of Chile is the geographical distribution of the generation potential versus consumption and the corresponding complications in the transmission

19. Sistema de Información Energética de Latinoamérica y el Caribe (http://sielac.olade.org/)

20. El Sector hidroeléctrico en Latinoamérica: Desarrollo, potencial y perspectivas / Arturo D. Alarcón. p. cm. — (Nota técnica del BID; 1405), 2018. DOI: http://dx.doi.org/10.18235/0001149

21. Hydropower Status Report 2018, – International Hydropower Association

grid which brings additional cost and environmental impacts for new developments. Further reforms in the water rights code will show how it can benefit new project developments. Hydropower generation has an important share in the short term, but the development of other non-conventional renewables technologies together with the increase in demand will reduce this share in the medium to long-term.

In Mexico, since the year 2017 hydropower generation is one of the main sources of energy generation making for 80% of the country's renewable energy supply and 17% of the country's total installed capacity. The country's government has imposed new reforms to the energy sector which are allowing equal conditions for public and private companies to participate in the energy market[22].

In Paraguay, the electricity generation is coming 100% from renewable energy sources. This is generated by the 14,000 MW Itaipu, the 3,200 MW Yacyreta and the 210 MW Acaray hydropower plant. These three plants have a production capacity close to 60,000 GWh per year. Comparing the 2018 domestic demand to the amount of the energy that is generated only 35% is consumed in Paraguay and the rest is exported to Brazil and Argentina making Paraguay the 4th largest exporter of electricity in the world. In an economic point of view, in the year 2017, Paraguay exported USD 2.1 billion which represented the 7.1% of the GDP[23].

In Peru, there had been a major energy reform in 1992-93, opening the market to private investors through long-term concessions to run the power sector more efficiently, since most of state-owned companies were facing financial problems. As of 2017, the share of private sector in generation was 78%, transmission 100% and distribution 65%. All companies are involved at the Committee of Economic Operation of the National Interconnected System (COES), which is responsible for a centralized operation of the interconnected grid system. However, there is a significant gap in operational efficiency between private and public companies. For example, in 2017, the system average interruption frequency and duration were on average three times higher for the public companies respect to the private ones. According to COES, Peru's electricity demand has grown rapidly with its economy, increasing by more than 79% in the last ten years, in 2018 most of Peru's electricity demand was served by natural gas generation (55%) and hydropower (30%), while the actual trend on renewable energy (mostly solar and wind) is increasing. The Ministry of Energy and Mines (MEM) foresees, by the year 2020, 360 MW of additional power installed from renewable energy resources (hydropower under 20 MW and biomass) with a target of 15% of generation from renewable energy. Regarding future plans of modernization of the sector, most of them are focused on energy efficiency, for example the Ministry of Energy and Mines currently involve an ambitious roll-out plan for smart meters within an 8-year timeframe and a requirement that operators reinvest 5% of their revenues in modernization and efficiency-enhancing measures.

The advances in modernization of the hydroelectric sector in most LAC countries takes place after market opening with the concession or sale of plants that were managed by state companies, many of them with financial problems (e.g., CEMIG in Brazil or the modernization of the plants sold by ElectroPeru). Basically, investment in modernization and technology in LAC is being developed mainly by private investors (global market players worldwide with investments in LAC, such as Engie, Enel, CTG, SPIC, etc.) because most of the hydropower plants in the LAC region are owned by private investors. Of course, these don't take away the fact that in some countries like Brazil and Colombia it's the other way around. Taking into consideration that a notable number of hydropower plants were built 30 to 40 years ago, rehabilitation and refurbishment of these plants will take place in the next decade. Although less new plants will be built compared to the past due to competing technologies (other renewables and natural gas) and preferences on short term return on investments, hydropower will increase in installed capacity due to new plants, and the upgrade and modernization of this elder fleet.

22. Hydropower status report (IHA, 2018)

23. Hydropower status report (IHA, 2019)

According to IDB[24], the demand for energy in LAC is projected to continue to grow at high rates in the next decades. Electricity demand in the LAC region is expected to double, from 1550 TWh to 2800–3500 TWh, in the year 2040. To be able to supply this demand, LAC will need to add 408 GW of new capacity, with and estimated investment of US$24 billion a year up to 2040. Moreover, considering the age of some power plants, by 2040, approximately 163 GW of installed capacity will reach their useful life, and would need to be replaced, with an additional cost of US$177 billion. Investment requirements could fall considerably under a development path that emphasizes efficient use of existing infrastructure, grid-connected renewables and a menu of demand-side solutions. In this regard, digitalization promises to bring significant values to the sector

24. The energy path of Latin America and the Cabbean (IDB, 2018)

3. THE IMPORTANCE OF DIGITALIZATION FOR THE HYDROPOWER SECTOR

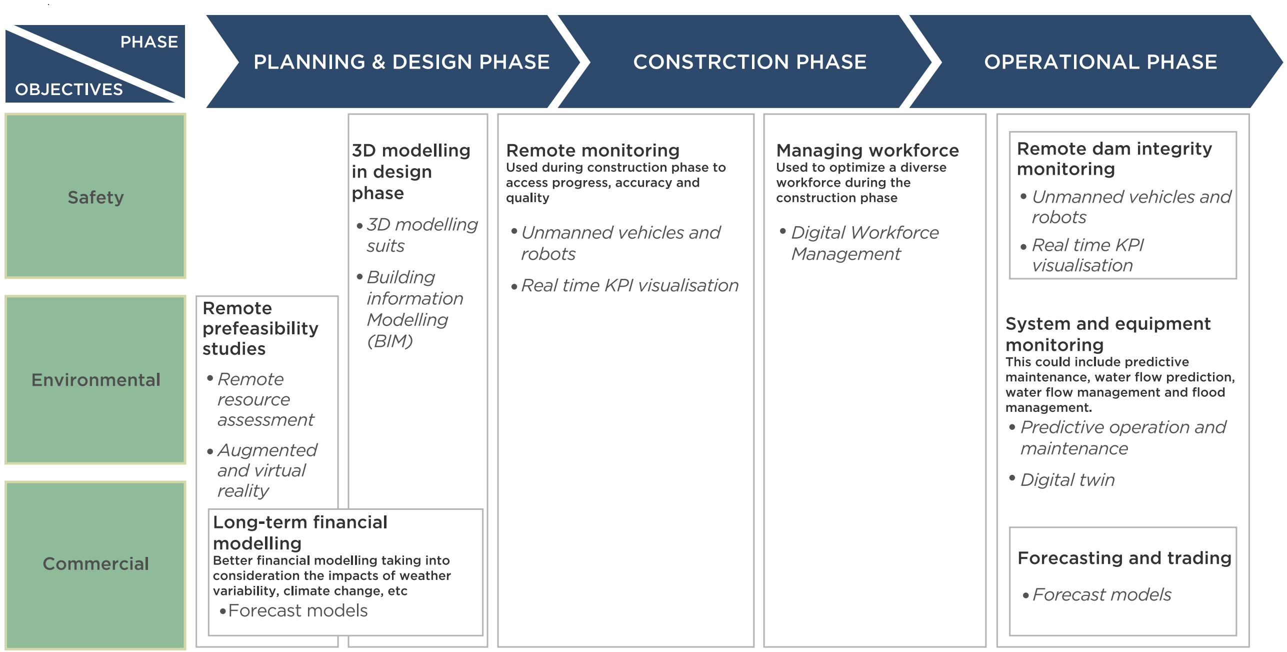
Digitalization and innovative technologies described in the previous section have been increasingly used at all phases of hydropower development from investment decisions, design to construction, operation and maintenance (O&M) to modernization and rehabilitation. They can be applied to satisfy one or more high-level objectives including:

- Safety – such as the integrity of dams, integrity of the hydro system and equipment;
- Sustainability – such as water levels, ecological flows, climate change impacts, water quality, fish management, etc.
- Commercial – both the short-term operation of plants and the long-term strategic investment decisions and so on. This includes more efficient operation and maintenance (O&M) of plants.

These objectives could be met by a variety of digitalization projects at different stages of the project life as illustrated in Figure 10.

Figure 10: Potential uses of digitalization that could be utilized in the lifecycle of hydropower assets to fulfil key objectives

Source: Pöyry Energy Business Group



Digitalization adds undeniable value to safety and environmental objectives, with indirect impact on the financial benefits regarding the reduced/avoided costs. On the commercial side, the immediate benefits of digitalization can be summarized as reducing operation and maintenance (O&M) costs; improving power plant and network efficiency; being able to coordinate future maintenance with hydrological data and future energy value; reducing unplanned outages and downtime; and extending the operational lifetime of assets – hence maximizing the profits from a power plant investment. The benefits for a few of these opportunities can be summarized as follows:

- Reduced staff costs during planning, design and construction phases: Remote pre-feasibility studies provide considerable decrease in staff-time required for travel and time on potential construction site. Likewise, remote monitoring also reduces the man-hours required on site, also enhancing the safety and quality of the construction works, enabling access to dangerous zones (e.g. underwater inspections, tunnels, etc). Digital workforce management is another means of digitalization which optimizes the workforce, thus reducing the staff-cost.

- Improved return on investment: Digitalization provides sophisticated modelling capability in terms of demand and supply forecast, regarding various weather parameters and climate change impacts, thus it is expected to reduce the error margin in planning hence increase the return on investment.

- Optimized operational revenues: Digitalization enables real-time monitoring and better forecast capabilities, therefore increases the immediate response capability; and even automated adaptation of plant parameters.

- Reduced outage and downtime: Real-time monitoring and increased data analysis capabilities change the O&M pattern from preventive to predictive O&M, resulting in considerable decrease in plant forced outages and extended maintenance intervals.

- Improved dispatch: Digitalization introduced a step-change in market and inflow forecast capabilities, incorporating plant data (i.e. so that the models can determine short- and mid-term availability based on sensor data analysis), plant owners/operators also can now optimize their dispatch pattern, in coordination with other renewable energy sources with respect to plant availability, environmental (inflow) forecasts, coordination with other renewables plants and market conditions (i.e. prices in different markets) together, ensuring safe operation of the plant and maximized revenues.

- Decreased cost for O&M: Inspection, repair and maintenance activities are improved by the support of mobile tools and services, such as machine assisted controls. This in turn leads to a lower demand for field experts, as the assets can be partially monitored and controlled from remote. The mentioned applications lead to new data sources, which can be – together with existing data – utilized for further optimization via data analytics and data visualization.

- Augmented Safety of operational staff: As explained earlier, drones, robots and sensors can be used to collect data, or even for repair/maintenance in dangerous zones such as confined spaces or underwater areas. Virtual reality can be also applied for staff training purposes as well.

- Increased security: Real-time monitoring of sensor data predictive maintenance and better inflow forecast capabilities increase the security of the system and the environment, as it provides early detection of failures and their impact, e.g. preventing liquid/gas leakage, explosions, better water management to avoid floods, etc.

Another very important benefit of digitalization is the value added to the electricity system operation (in addition to the direct revenue benefit to the plant owner/operator) by improving the use of flexible generation. There has been a huge increase in the intermittent (or variable) renewable energy generation (i.e. wind and solar, in particular) all around the world, which poses challenges to system reliability and requires improved access to flexible generation to provide essential balancing services and energy storage required to mitigate the variable renewable energy sources. Hydro power plants, in particular those with daily, weekly or seasonal reservoirs, play a very important role in this respect due to their storage capability.

As explained earlier, digital technologies provide the opportunity for better forecast of generation, which includes generation from wind/solar resources. Accordingly, hydro power plant operators can plan their short- to mid-term scheduling, also considering the requirement for flexible generation, and can use digital tools to offer even greater real time flexibility. This would mean increased system reliability for the system operator and increased revenues for the plant owner/operator from the flexibility markets. However, the order of benefit regarding optimization for short term flexibility (including ancillary services) also depends on the energy market design (e.g. whether there are real time markets) and how the dispatching of the plants is controlled (e.g. marginal cost model with centralized plant dispatching such as in Chile).

Older power plants have traditionally been difficult to automate as they required replacing mechanical equipment that does not interface with SCADA as well as the entire SCADA system. IoT Sensors and devices are able to operate outside the SCADA world, and can thus allow for partial upgrades of older plants, as a transition for further upgrade to SCADA if needed. Also from a planning perspective, automated planning solutions allow for a more efficient evaluation of rehabilitation potential and may be quicker in identifying a suitable economic solution for it. Digital monitoring systems and digital control systems are the digital technologies that most LAC hydropower companies use as mentioned above.

But digitalization is not about technology per se; it must be underpinned by sound cybersecurity and strong digital transformation principles. The cybersecurity risk arises through increased automation and more exposure to various sources of information which drive the decisions, which is often coupled with reduced involvement (and oversight) by humans in the process. Taken together, this increases the vulnerability to cyber threats meaning companies have less visibility of when things go wrong, and indeed, how to stop the processes if they do. Moreover, as more and more assets become connected, the challenge might be to identify which are the critical assets, every sensor and every component that is able to be connected to the internet must have a risk assessment, so to prevent increasing the risk of the whole system[25]. This growing exposure has led some governments to set up departments to protect national power grid infrastructure against cyber-attacks e.g. in the US the Office of Cybersecurity, Energy Security, and Emergency Response was established followed a hacking campaign in 2017 that targeted a number of electricity companies. Large infrastructures like nuclear and hydropower plants are particularly attractive targets.

It is important to understand that digital technologies can be at all stages of a hydropower plant's lifecycle which is explored in the next section.

25. https://www2.deloitte.com/insights/us/en/industry/power-and-utilities/cyber-risk-electric-power-sector.html

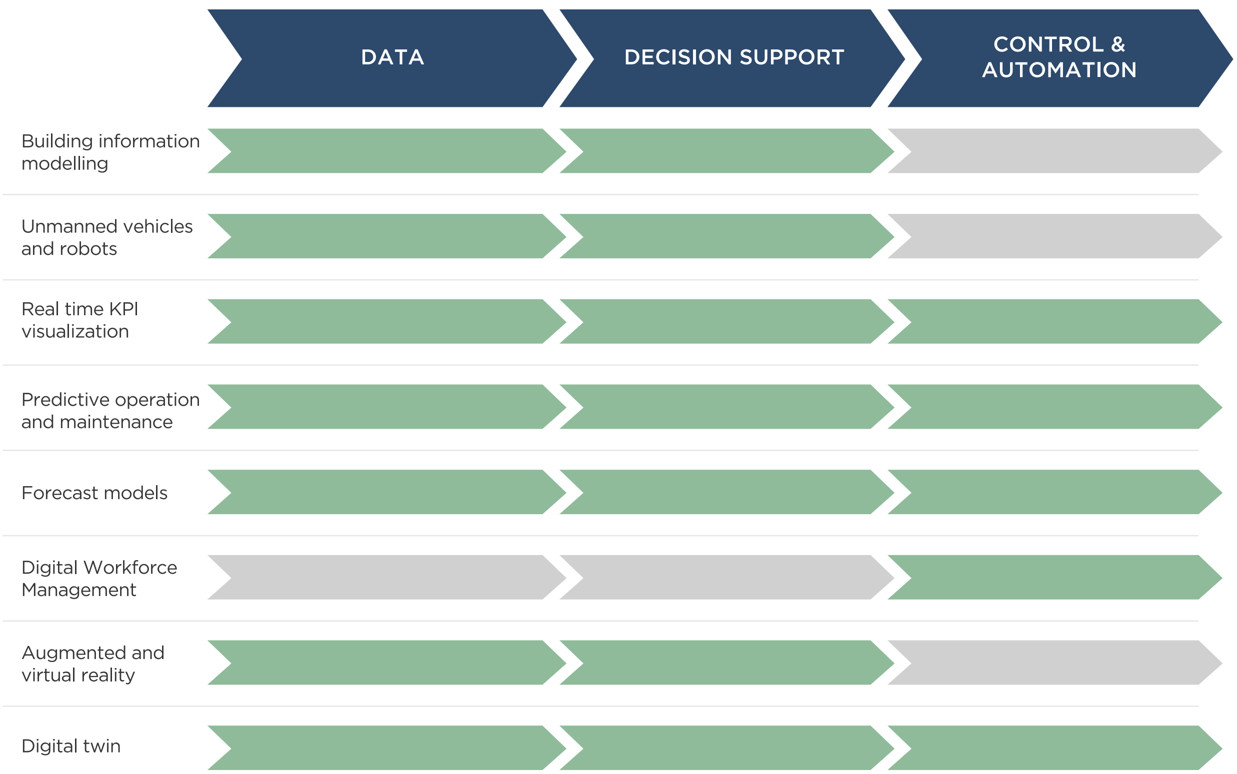
4. OVERVIEW OF DIGITALIZATION TECHNOLOGIES (RELEVANT TO THE HYDROPOWER SECTOR)

Digitalization increases the ability to collect and communicate data; process this data to make better decisions; and potentially to automate the execution of decisions. This section provides the functionalities and benefits of several digital and innovative technologies individually.

Figure 11 shows an overview of where these key technologies fit in the digital value chain given in Figure 1 in Section 1.1 as well as the driving technologies stated in Figure 7. Nonetheless, as many sensing and analysis technologies evolve, the graph might change in time (for example, data driven work force management and decision support can be easily foreseen).

Figure 11: Digitalization technologies and their place in the digital value chain Green colour indicates the applicability of each technology

Source: Pöyry Energy Business Group



Green colour indicates the applicability of each technology

Building Information Modelling (BIM)

BIM provides 5D models of larger hydropower projects of all types: it enables the augmentation of 3D models (i.e. spatial dimensions: height, length and width) with a fourth dimension, time (making it 4D); and a fifth dimension, cost (making it 5D). BIM is achieved by compiling and processing data on (i) spatial dimensions by laser scanning or photogrammetry, enhanced with visual material from drone photography; (ii) costs (i.e. recent costs of equipment/materials to repair/replace); and (iii) day-to-day operations to assess the use-time and thus the time left to repair/ maintenance/ replacement.

BIM technology increases the transparency and efficiency in operation and maintenance/ rehabilitation, thus the data from BIM can be used to reduce the O&M costs further. BIM is an essential starting point for a digital twin (see below), which at the simplest level combines a static view of the installation with a real time representation of its operating status.

During the design and planning phase of a hydropower plant, BIM technology is critical to ensure final CAPEX figures and to avoid future incompatibilities or difficulties in the integration phase e.g. between E&M and civil works. Furthermore, the experienced use of BIM will help making it easy to implement design changes and providing the input data for a lean and transparent project management during construction phase. In LAC, BIM can be a key element for the coordination of different work fronts (with different contractors), including the equipment supply chain, helping to reduce cost increases and time delays, very common in hydropower development in the region[26].

Unmanned vehicles and robots

Unmanned vehicles, also known as ‘drones’, and robots with remote sensing technology allow improved inspection, with increased security, at all stages from design to construction and operation (Figure 12).

In the planning and design phase, drones can be used to realize preliminary site survey which improves project costs and accuracy of baseline topography in cases where satellite information is not up to date and accessibility is limited.

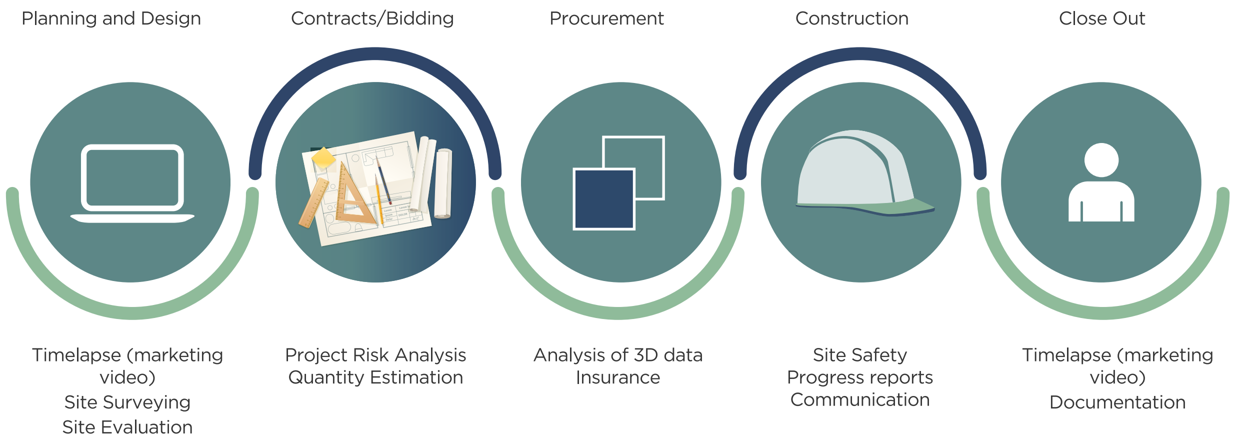
In the construction phase, drones and diving robots with sensors and actuators can enable progress monitoring and high accuracy digital surface modelling.

In the operation phase, diving robots and drones can also be used to support inspection, building and maintenance tasks under water as well as in confined areas. They are mainly used where deployment of humans is too dangerous, too expensive or simply not possible. This means increased safety due to reaching inaccessible areas and, occasionally, cost reduction. For example, Enel Green Energy Chile has started to use robots in their hydro utilities to enable inspections on pressure pipes and be able to measure sedimentation volume on reservoir dams.

Ultimately drones are a rich potential source of data (particularly in tunnel shafts and hazardous areas) which can underpin many other digital initiatives which relate to decision support or automation.

26. El Sector hidroeléctrico en Latinoamérica: Desarrollo, potencial y perspectivas / Arturo D. Alarcón. p. cm. — (Nota técnica del BID; 1405), 2018. DOI: http://dx.doi.org/10.18235/0001149

Figure 12: How Drones Are Being Used Across the Construction Project Life Cycle - Source: https://medium.com/@askdroneu/how-drones-are-being-used-across-the-construction-project-life-cycle-9ce504394e60



Real time KPI visualization

Real time Key Performance Indicators (KPI) are used as a part of Operational Excellence programs, where key KPIs, such as power factor, asset health, availability, etc. are directly integrated with the plant's financial KPIs, usually from the Enterprise Resource Planning (ERP) System, to immediately assess the business impact. Within this process, the operational KPIs are continuously calculated from floor parameters (equipment/machine), and combined with what-if analyses are used to visualize the impact of change to each parameter on the business KPIs. For instance, it is be possible to calculate in real time the operational costs ($us/MWh) for a specific plant, given certain plant conditions, which would allow for comparison with benchmarks[27] or with other plants, or even to conduct a what if assessment to decide whether to enter into the market or not.

Predictive operation and maintenance

Digitalization and the wealth of data underpinning it enables fault prediction and dynamic maintenance. This is one of the clearest uses of artificial intelligence (AI) in hydropower, which enables operators to predict equipment failures well in advance, by using sensor data from various units to significantly reduce their costs of downtime and maintenance.

Predictive O&M collects real-time data and processes it, also in real-time, with machine learning algorithms (also correlating to BigData, if/where applicable) assessing against critical parameters, such as temperature, vibration, corrosion, short-circuit currents, etc. and detecting potential failures and scheduling maintenance accordingly through data analysis, optimization and automation. In this regard, for example, the Columbia Water Center in the USA is developing a project that would use climate models, GIS data and artificial intelligence to predict the probability that rainfall will overtop a dam and cause significant downstream damage to the population and to critical infrastructure[28].

27. See for example: Benchmarking of Hydropower Plants https://www.hydropower-evolutions.com/documents/140918ENGHydroBenchmarkingPresentationatVGBConferencefinal.pdf

28. https://www.hydroworld.com/articles/2018/08/using-artificial-intelligence-as-a-tool-to-locate-risky-dams.html

Currently Statkraft Peru in its Control Center receives more than 15,000 analog and digital signals information from their 9 power plants. Due to that amount of information they developed an artificial intelligence system with more than 5 million data inputs to train the AI with a neural network that allows the early detection of faults in the hydraulic unit of the Malpaso Hydroelectric Power Plant.

Forecast models

Inflow and market (i.e. price) forecast models have also considerably improved in today's technology, due to improved weather forecasts and ability to implement real- and near-time data to the forecast models. Forecast models can also be enhanced to produce even more accurate results by artificial intelligence based on BigData and plant data analysis and machine learning.

In the design phase, this means better planning of the investment both in technical and commercial/financial terms, i.e. potential earnings and project finance. In the operation phase, forecasting tools can be enhanced by incorporating the sensor data from the plant help optimize operation of the power plants to minimize production losses. This can be extended to include water management optimization systems to manage inflow variability and mitigate risks such as floods and droughts, ultimately targeted at maximizing earnings from different markets (electricity, flexibility, ancillary service markets, as well as other benefits such as irrigation) by much more efficient regulation of the water with respect to forecasted weather conditions, asset performance and market conditions. Likewise, when plant owners have a diverse portfolio, which might include wind and solar power generation, forecast models can help to optimize the whole portfolio production and market participation.

Forecast models can also be combined with algorithmic trading, which means automation of the trading offers based on forecast models enhanced with artificial intelligence. In this context it is worth mentioning that in the year 2018 machine learning was introduced to hydrological modelling by Statkraft Peru. A hydrological model of a basin using Big Data has been developed with the aim of having a better prognostic within a time period of 3 to 5 days.

According to the Financial Times, systematic and algorithmic trading now account for nearly 60% of the traded volume on just the Chicago Mercantile Exchange energy product group, i.e. the highest level of any commodity group. Anecdotal evidence (from the exchange) states that by mid-2018 over 50% of trades on EPEX spot intraday market were algo-trades, although the total traded volumes were smaller than those traded manually by humans.

Digital Workforce Management (WFM)

Digital WFM solutions assist the O&M staff in routine work in terms of operation scheduling and documentation: Mobile digital solutions replace analogue machinery books by enabling staff to review and input maintenance data directly on site and report automatically to centrally managed O&M platforms, which decreases the administrative effort and ensures the clarity and efficiency of maintenance processes. In combination with staff availability data, this results in various degrees of automated decision making on maintenance schedules from simple optimization algorithms to complex machine learning systems. This allows an effective deployment of the maintenance workforce and therefore greatly helps to improve the availability and reduce O&M costs. In Peru, Statkraft uses its own app for supervision works. This app saves them man hours and paperwork, moreover the centralized control office can know what is happening at real time.

Augmented and virtual reality

Augmented and virtual reality is a data visualization tool applied on various stages of a power plant from investment decision to design and planning to maintenance and workforce training. The visualization of models improves the cooperation of design, planning and operations teams from different disciplines. Mobile solutions provide the maintenance workforce with real-time information (e.g. from cameras or 3D-scanners), documentation and reporting. Virtual reality and 360° videos enable training on operating assets which have limited or no access,

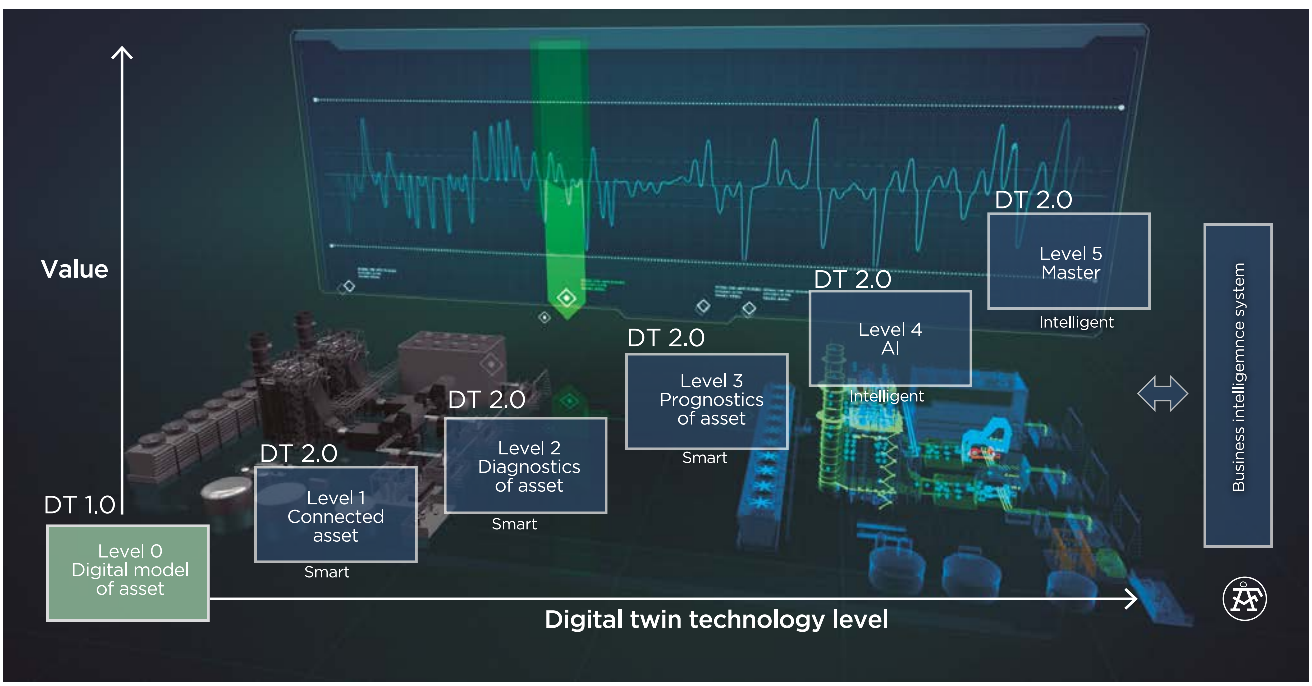
such as impellers or generator rotors. Furthermore, and in the context of rehabilitation, 3D scans help to rebuild the technical environment in an efficient & detailed way allowing a cost efficient and tailor-made rehabilitation design. Coupled with Computational Fluid Dynamics (CFD) hydraulic software 3D scans help to understand the weak spots of existing plants and thus provide further information regarding a problem orientated cost-efficient design. Pöyry in Peru has done for example 3D scans to recreate hydropower generators to identity if there are any deviations on the rotor and stator; as well as 3D simulations of a possible dam break to explore a solution. Many companies as well are using mobile devices to support maintenance staff in the plant. In this respect companies are also using QR-Codes to identify specific components and measuring devices.

Digital twin

Digital Twin are perhaps the most powerful application of digitalization in hydropower (Figure 13). It creates an exact replica of a technical component by combining mathematical models with sensors and data measurements, on a virtual environment via Internet of Things (IoT) . The mathematical models and real time measurements help get exact replicas via an iterative process, where the mathematical model is refined permanently with the real time me-asurements. A digital twin is not only a visualization tool, but a simulation and evaluation tool that replicates exactly the behavior of a component, under real or simulated conditions. Sensors attached to key components collect and process real-time data so that the digital version can act like the real object, allowing the staff to remotely monitor the component, easily detect faulty items and take immediate actions on-site, or even simulate what-if scenarios of stress in the plant.

Depending on the purpose, digital twins can be done system-wide, for complete plants or only for sensitive parts of a plant. The benefits of their application range from improved maintenance, to dam safety. Gains in operation and maintenance costs are expected to be US$000 per MW per year[29]. For instance, Voith has implemented a sound analysis system, that permits to identify the causes of reduced efficiency and failures via a digital twin[30]. Similarly, General Electric created a virtual representation of a hydropower plant in the cloud and used data to compare it to its real-world condition, which has improved its reliability by at least 1% or greater. This improvement at global scale would represent 413 GWh of incremental hydro generation due to increased uptime.

Figure 13: Digital Twin value levels - Source: AF Energy Business Division



29. https://www.ge.com/reports/dam-powerful-ge-connected-hydropower-internet/

30. https://stories.voith.com/voith-optimizes-physical-assets-with-the-help-of-their-digital-twins-thereby-opening-up-new-business-opportuni-ties-53920/en

5. LEVEL OF DIGITALIZATION IN HYDROPOWER IN LAC

A general overview of the state of digitalization in LAC has been provided in Section 1.2. In summary of the previous sections, the level of digitalization in the different energy markets in LAC basically depends on the structure and the organization of the electricity markets as well as the existing communication infrastructure and legal framework.

According to Pöyry Energy Business Group's experience in most LAC countries private energy generators, which are mainly linked to European and US companies and representing the major part of the electricity markets, are implementing the lessons learned from their home countries in the local markets with the back-up of local and foreign capital. For the more newly-built facilities, SCADA systems represent a standard design requirement allowing the implementation of further future digital technologies and communication with each part of the plant.

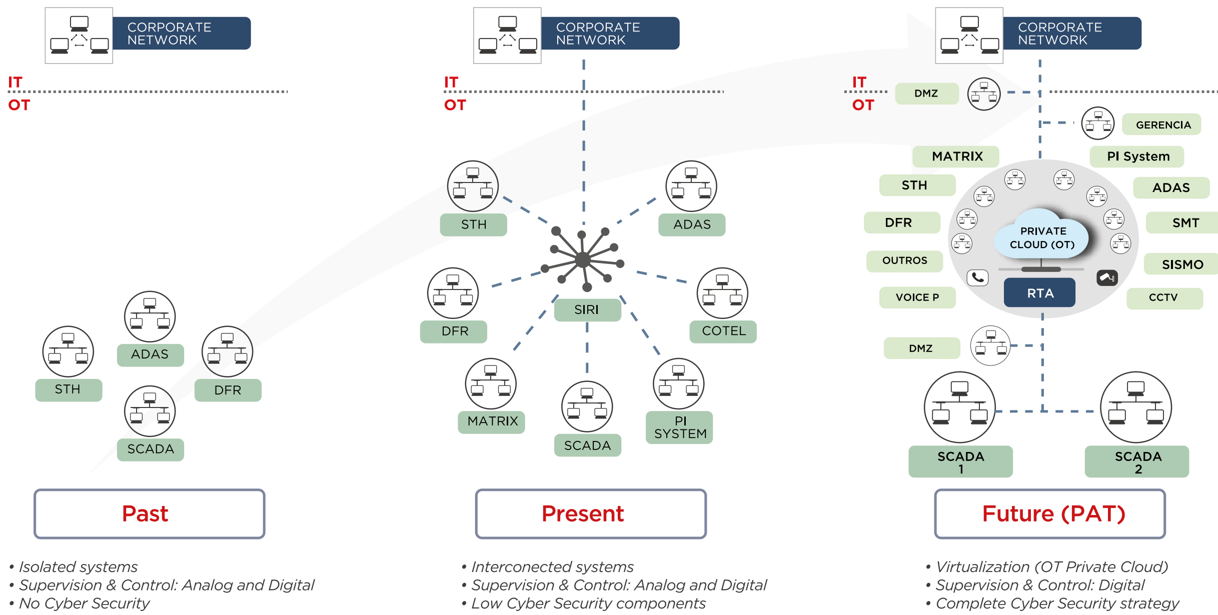
Centralized operation is one of the main goals when talking of digitalization in LAC taking into consideration the upgrade and modernization of the older plants. Peru is a leading example for centralized operation in LAC, where the local electricity system operator COES remotely manages the dispatch of the plants to maintain the frequency of the system. This has been achieved by connecting all generators via fiber-optic cable to the centralized dispatching center located in Lima, which forced the generators to invest in digital technologies to comply with the system operators' communication requirements. Furthermore, generators are aware that they must follow the pace of digitalization to earn future benefits in terms of more efficient generation and reduction in costs due to more accurate and foresight maintenance programs, whilst implementing improved safety processes. Nevertheless, this notably depends on the available funds to realize these investments, which in the case of private investors does not represent a major constraint across LAC countries.

In addition to the generation facilities, transmission and distribution systems are also facing the digital revolution. According to ABB, the majority of electrical substations operating in Peru are conventional; and regarding the fact that digital electric substations can reduce up to 30% of the total construction costs, and 70% of the O&M costs, the system operator is highly interested to implement these new technologies.

Further recent well known examples for digitalization come from Brazil, Argentina, Uruguay, Paraguay and Chile. The recent international workshop called "Digitalization in the hydropower sector" in 2018, carried out in Salto Grande Hydroelectric Complex (Argentina and Uruguay), showed their achievements which are presented and shared via the websites of the different companies, underlining that digitalization is already a driving factor in the hydropower business for the last decade in LAC.

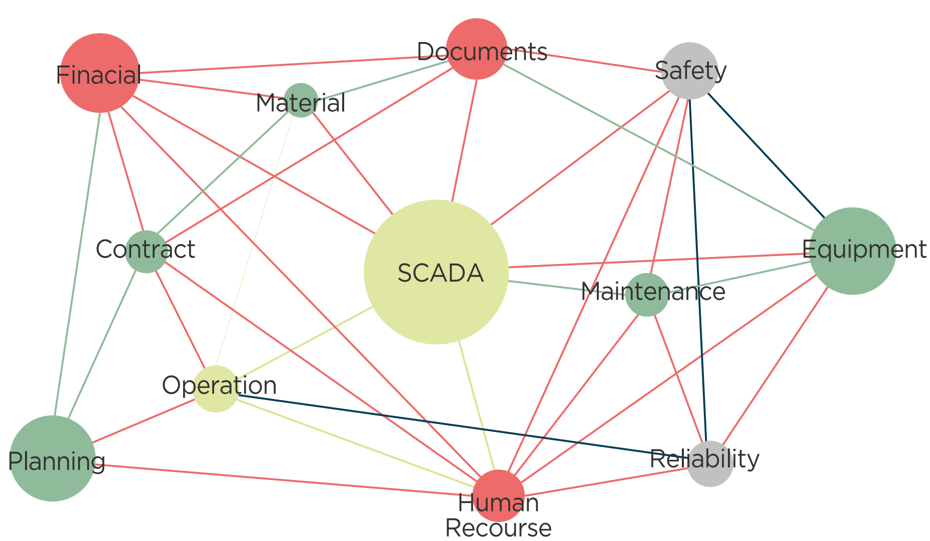
In particular, centralized control system emerged initially in the year 2003 taking advantage of the interconnection and possibilities of the new digital technologies e.g. in the "Itaipu Binacional" project between Brazil and Paraguay (see Figure 14). The project's schematic helps understand how all the operational technology (OT) (listed in the Figure) will work synchronized so that the users can see and control the hydropower's performance in the external interface (IT). Given the size of this power plant, the project is being implemented in several stages, interconnecting gradually all of the plant's operational technologies, and eventually collecting, storing and analyzing (in the future) all the information in the cloud. A key aspect in this process is the need for a multidisciplinary team. Moreover, given the pace of technological developments, digitalization might require a constant upgrade of the systems. Cyber security is also a key aspect, which will have to be built gradually as the complexity of the digitalization increases.

Figure 14: Evolution of the Itaipú binational monitoring system - Source: ITAIPU BINACIONAL, Modernization Project presentation at the 27-28 august 2018 Salto Grande workshop



Another example which is shown in Figure 15 is CTG Brasil, which has modernized their hydropower plants Ilha Soltteria and Jupia by upgrading the SCADA system with the aim of having an interconnection between site-operation and the company's operation, building a bridge between IT and OT. Another aim is to connect not only the O&M but also other areas like safety and finance, so that decision making is done more accurately. Additionally, all the analog operation, control and monitoring systems will be replaced by digital systems, and the power plant operation will be automated with the main objective to increase its efficiency, security and reliability.

Figure 15: Organization strategy of CTG Brazil - Source: CTG Brasil, The Modernizationof ILHA SOLTERIA HPP and JUPIA HPP in brasil at the 27-28 august 2018 Salto Grande workshop



In the same way, Salto Grande that is shared by Argentina and Uruguay and also Yacyretá (shared by Paraguay and Argentina) are planning to take advantage of digital technologies transforming some of their electrical equipment into digital equipment entirely monitored via the SCADA system. Salto Grande's main objective is to have the control and protection equipment digitalized to ensure that the facility is well prepared for future operations, within its long-term modernization program.

Also, in Chile the company Enel has implemented low-cost wireless meteorological sensors capable of self-powering and ideal for remote areas that are difficult to access. Their aim is to increase safety of the power plants in order to improve and optimize them and thus reduce the cost of O&M processes.

It is important to note that most of these changes and modernizations in the hydropower sector are implemented by the different business areas and not by a proper digitalization division per se. That is, this companies are not implemented a fully develop "digitalization strategy", rather, different digitalization actions (sometimes not coordinated). For example, the O&M could have one project and the commercial area could have another one. This might have higher costs and could also cause a conflict in the long run (due to compatibility issues). It is important to mention this because even though LAC is implementing digitalization solutions, it is not yet organized and fully aligned along the entire supply chain. Furthermore, apart from the technical implementation digitalization is also introduced in the non-technical areas of the companies like legal and social-environmental divisions. All these efforts still need to be bundled and a general digitalization strategy has to be built within the hydropower generators in LAC.

5.1

CASE STUDIES, EXEMPLYFING THE CURRENT STATUS OF DIGITALIZATION IN LAC.

As indicated in section 1.2, digitalization in LAC is lacking behind the developments seen in OECD, China and US. Although this fact is discussed in many publications, it is relevant to distinguish between the public and private sector. In the energy sector it is expected that there will be an increase income due to digitalization across the whole process starting from generation up to the end client marketing. With respect of the current status of digitalization in hydropower the countries Chile, Mexico and Peru were selected as they are representative of the region, and also covering the entire span of development level from most advanced (Chile) to lagging behind (Peru), with Mexico in the middle. Hence to get more insight to the actual status and digital initiatives in the private hydropower sector the following companies were interviewed:

- Colbún S.A. (Chile - https://www.colbun.cl/)
- Pacific Hydro S.A. (Chile – https://www. http://pacifichydro.cl/)
- Generadora FENIX (México - http://www.fenixenergia.com.mx/)
- Statkraft Peru (https://www.statkraft.com.pe/)

The interviews were held in the offices of the above mentioned companies or via video conference. To get an overall view of digitalization in hydropower following questions were raised during the interviews:

1. What is your understanding of Digitalization in Hydropower?
2. Is digitalization playing a role in the company's PR/publicity?
3. Are there specific projects done/ongoing/foreseen? If yes, which are these?
4. How will Digitalization/these projects impact the future business (Expectations)?
5. What are the major risks/threads when dealing with digitalization in Hydropower (IT/skilled staff/cost/etc) ?
6. Where do you see the major potential of digitalization in Hydropower (operation/construction/rehabilitation/etc.?)
7. What are your experiences/learnings regarding digitalization so far?
8. Do you have a Digitalization Strategy in place, or will you have one in the near future?

CHILE

COLBUN

Colbún S.A. is a company of Chilean origin dedicated to the generation of electric power. It has 26 generation plants in Chile and Peru with a total installed capacity of 3,893 MW distributed in different types of generation technologies. The company also has 941 kilometres of transmission lines and a total of about 1,000 employees. Colbún owns and operates 4 reservoir (1035 MW) and 13 run of river (565 MW) hydropower plants in Chile.
The interview with Colbún (COL) can be summarized as follows:

- Digital Transformation of the company and its processes is a strategic axis for the modernization of the company.

- Currently this means the re-engineering of all processes and internal procedures starting from the O&M of the plants but also the business and client service areas.

- As a first stage and depending on the current status of each plant, this means automatization and centralization of control buildings for remote control of plants or certain groups of plants. Implementation is a three-phase approach of which one of their plants will reach phase 3 and thus have complete remote control.

- Proposed digitalization measures are evaluated under a cost-benefit scheme before implementation.

- Future potential is seen in the simplification, with the use of AI, of O&M concept changing from preventive maintenance to condition maintenance.

- Simplification in O&M also means reduction in staff. Reduced response time for reporting in case of any failure or outages; and also, a reduction in time processing of data analysis.

- Adapting to new business needs: i) installing smart meters; ii) collecting detailed and more granular data from clients; and iii) consulting clients to improve their energy consumption profile, in order to have access to more attractive agreements.

- Client needs are getting more demanding, regarding other services, such as distributed energy from solar roof, charging stations for EVs, etc. For this, a proper back office needs to be built up for analysis of the client data and in a further step automatization of client services.

- Main potential in digitalization is seen in the automatization of plant control.

- Communication infrastructure outside of Colbun's property is a limiting factor in the implementation speed of above-mentioned measures.

Pacific Hydro

Pacific Hydro is a global provider of clean energy solutions. Operating for more than 20 years, the company develops, builds and operates renewable energy projects and sells electricity and carbon abatement products to customers in our markets. They have hydropower and wind power projects at different stages of development, construction and operation in Australia, Brazil and Chile, with a vision of creating economic, social and environmental value by being their customers' preferred provider of clean energy solutions.

Present in Chile since 2002, Pacific Hydro produces clean energy through its run-of-river hydropower plants in the country's Region VI. Projects in operation include the Chacayes, Coya and Pangal hydropower plants in the Cachapoal Valley, and La Higuera and La Confluencia in the Tinguiririca Valley through the Tinguiririca Energía joint venture. Since 2018 Pacific Hydro has operated its first wind farm project in Chile, Punta Sierra, located in Ovalle. In addition, it continues to develop its line of 500MW run-of-river hydro projects in the Cachapoal Valley. Founded in Australia in 1992, Pacific Hydro is owned by State Power Investment Corporation (SPIC), through State Power Investment Overseas Co., Ltd. of China (SPIC Overseas).

SPIC is one of the five largest power generation groups in China, with total assets of US$113 billion and total installed capacity exceeding 126 GW. SPIC operates in the generation, coal, aluminum, logistics, finance, environmental protection and high-tech industries. SPIC is present in 41 countries and regions abroad, including Australia, Chile, Malta, Japan, Brazil, Turkey and Vietnam.

The interview with Pacific Hydro Chile (PHC) can be summarized as follows:

- Internally the process for digitalization started around 2-3 years ago and the program consists of several pillars: Cloud Computing, Big Data Analytics, IoT. All of these must be under a corporate cyber-security concept.

- Within the scope of IoT, they collect data of all sensors and equipment and send it to a central data storage.

- Main motivation to invest in digitalization in the first place is, to modernize the oldest plants in order to increase availability and decrease outage times.

- There is not yet a clear picture of how much the economic benefit of Digitalization will be but PHC is convinced that the investments will have a positive impact.

- First primary goal already realized were the:

- Installation of a high-quality data center by end of 2017

- Second step is digitalizing OT and define data quality

- Older powerplants with many analog systems must be changed in coordination with O&M staff according to their priorities.

- PHC today is in the situation that the preventive maintenance is still predominating due to some high failure rates in their older plants (more than 100 years). Therefore, first step is modernizing, exchanging failing components with new ones to reach benchmark levels of component availability. Only then it is possible to switch to predictive maintenance based on digital data from component sensors in the plant.

- In the vision of PHC and based on IoT, the system can self-maintain components, measure wear and tear of

equipment and order services from the equipment provider up to automatic ordering of spare parts based on predictive failure rates.

- PHC priority is on the older plants to reach a reasonable level of plant availability before bringing the modern plants to IoT level due to the greater economic impact.

- A Global Operation Center with all power plants (Chile, Brazil, Australia) is currently in testing phase.

- Lack of suitable professionals is not an issue since more advanced countries and supplier can fully deliver an operating functional system including the corresponding training.

- Regarding communications over large distance there is currently an economical barrier to connect remote installations. However, there are new technologies that can solve this problem. On the other hand the government (SUBTEL) is still discussing under what standard these communications systems will be implemented on a national level which consequently slows the development down.

MEXICO

Generadora FENIX

“In Generadora Fénix we offer services of generation and sale of sustainable electrical energy to the wholesale market in Mexico. We have the technological capacity to offer renewable electric energy efficiently, reliably and with a superior level of service. Our proven experience in the sector allows us to offer flexible schemes that adapt to the needs of each of our customers.

Generadora Fénix arises in 2015 as the result of a strategic partnership between the Portuguese company Mota-Engil and the Sindicato Mexicano de Electricistas (SME) to proudly constitute itself as the first private company to participate in the opening of the electricity market in Mexico. This alliance arises to face the new configuration of the Mexican electricity market with the implementation of the Energy Reform. Mota-Engil brings its global experience, technological and financial capacity, solidity, social vision and a strong Latin American focus, while the Sindicato Mexicano de Electricistas (SME) is a partner whose human capital has extensive knowledge and technical capacity.

We have 5 hydroelectric plants in operation with a large production capacity of ~ 280 MW (Central Lerma 73.5 MW (3 units); Central Alameda 6.9 MW (3 units); Central Necaxa 108 MW (10 units); Central Tepexic 45 MW (3 units) and Central Patla 45 MW (3 units)). Our plants are strategically located in the center of the country, specifically in Mexico City, State of Mexico, Michoacan and Puebla, which allows us to have a very competitive position.”

The interview with Generadora Fenix (GF) can be summarized as follows:

- In the opinion of GF, digitalization is key for future performance of the company
- Main motivation to invest in digitalization is savings in cost and time
- Digitalization will have a main economic impact on the long term and a rather limited impact on the short term
- First primary goals already realized: Centralization of the operation in Mexico DF
- Creating a data center in Mexico DF, where all data of the plants are received with
  1st: Gathering all the data from the different plants
  2nd: Organizing all the data in an intelligent way
  3rd: Applying specified and tailor-made analysis on the Big Data
- Besides the centralized operation, organized & well-planned predictive maintenance shall be achieved with digitalization. Basically, digitalization of the plant will:
  - Improve preventive maintenance based on different measurement parameters (e.g. recorded failures, sensor data, etc.)
  - Better organize the maintenance works in terms of manpower, foreseen time and loss of energy generation
  - Allow to have better time management for maintenance over the entire fleet
  - Reduce deterioration of the assets

- Regarding the rehabilitation of elder plants digitalization is seen to support:
  - Increased flexibility and quicker decision making
  - Efficient control of the works
  - Exchange of modifications / changes with authorities or 3rd parties
  - Traceable way of communication and related responsibilities
- Although up to now lot of positive results were obtained by implementing digitalization measures, there are still some open issues to be solved:
  - Results or suggestions coming from digital tools still have to prove their viability
  - Getting specific information out from the Big Data needs more investigations
  - Continuous learning and training of the staff is necessary and shall be adapted also to the evolving digital tools
  - Decision making based on results from digital tool still has to be improved

From the interview with FG we can conclude the following:

- Digitalization has proved its positive impact of reducing time and cost increasing earnings at the same time
- In Mexico for FG there is no problem to get trained staff or to get required digital solution from the market
- Although cyber security is on the discussion table it is not seen to be one of the major issues, as systems are running in a rather separate network and only specific people have access

PERU

Statkraft

Statkraft is a leading international hydropower company and Europe's largest renewable energy generator. The group produces hydropower, wind, gas and district heating and is a global player in energy market operations. Statkraft has 3600 employees in 15 countries.

The Peruvian electricity market is composed of the generation, transmission and distribution segments. Statkraft in Peru is present in the electricity generation and transmission segments through the operation of 9 hydroelectric generation plants and more than 920 km of transmission lines that serve an important part of the country's demand.

Statkraft seeks to strengthen its position as an international leader in the supply of renewable energy. Through its International Hydroelectric Energy division, it drives Statkraft Peru to strengthen the South American region through acquisitions and development of renewable energy projects, and the optimization of the potential of its assets and resources. Statkraft in Peru operates 9 hydroelectric plants in 6 regions of the country. It currently contributes 450 MW of clean energy to the National Interconnected System. Knowledge and synergies with the parent company allow you to create value for your various stakeholders.

The interview with Statkraft Peru can be summarized as follows:

- Statkraft has a clear idea that digitalization is a key step for the hydropower sector, since the year 2015, and that without it hydro power companies will be at a great disadvantage compared to those who are implementing it.

- Due to the low prices for energy in Peru Statkraft has realized that digitalization is the way to go because of the positive impact it will have, being one of these impacts lowering the cost in O&M.

- Digitalization has not only been implemented on the operation sector of Statkraft but also in the in communication, safety, legal and commercial sectors.

- Statkraft has developed many initiatives in regards with innovation like:

- Supervision / Maintenance reports are made with a smartphone app the company has developed reducing time and cost for the company.

- Statkraft has teamed up with the Pontificia Universidad Catolica del Peru (PUCP) to create drones that can detect and analyse the state of the transmission lines, possible new human settlements, embankments, dams and many other infrastructures which can affect the operation.

- Statkraft also developed a mechanic arm using 3D printing to be able to introduce a small camera into the generators for maintenance. This type of work is generally done by humans & thus the digital initiative reduces the risk of any possible injuries. Also, this idea was presented in a Mining Congress in Peru competition and they won first place.

- In the year 2018 machine learning was introduced to hydrological modelling of a basin using Big Data with the aim of having a better prognostic within a time period of 3 to 5 days.

- Statkraft developed a software to monitor and guide the staff operators in a virtual way in each step of the work sequence they perform, through augmented reality. This software has been customized to their needs. In

addition, this monitoring tool allows remote connection from the Lima Control Center to support remote operations. This way they avoid any error within their maintenance procedures and mitigate risks exposure of the involved staff.

- Statkraft has internalized the concept of digitalization and innovation and has developed company politics like:

- New personnel entering the company must have an innovation profile

- The company develops internal competitions to motivate innovation ideas, mostly in digitalization

- The company has renovated its office with innovation words to motivate the staff and also has created special locations within the office to motivate out of the box thinking.

- Statkraft has being a leader in hydropower digitalization in Peru, with actions like:

- When COES interconnected the hydropower plants to be able to control the energy generated Statkraft was one of the first company to have already all the equipment for this transition and also helped other companies to adapt to this new automation.

- Since the year 2008, Statkraft initiated the transition from mechanical operation to having a SCADA system implemented. It is important to mention that Statkraft has hydropower plants that have being operating since the 1930s.

- Being able to develop to fix problems with its own in- house expertise in regards with its automation instead of having to recur to other companies out of the country.

- Statkraft has exported its local in-house know-how to other countries like Chile and Brazil to help them with their issues in digitalization problems; and has trained them to be able to work on their own.

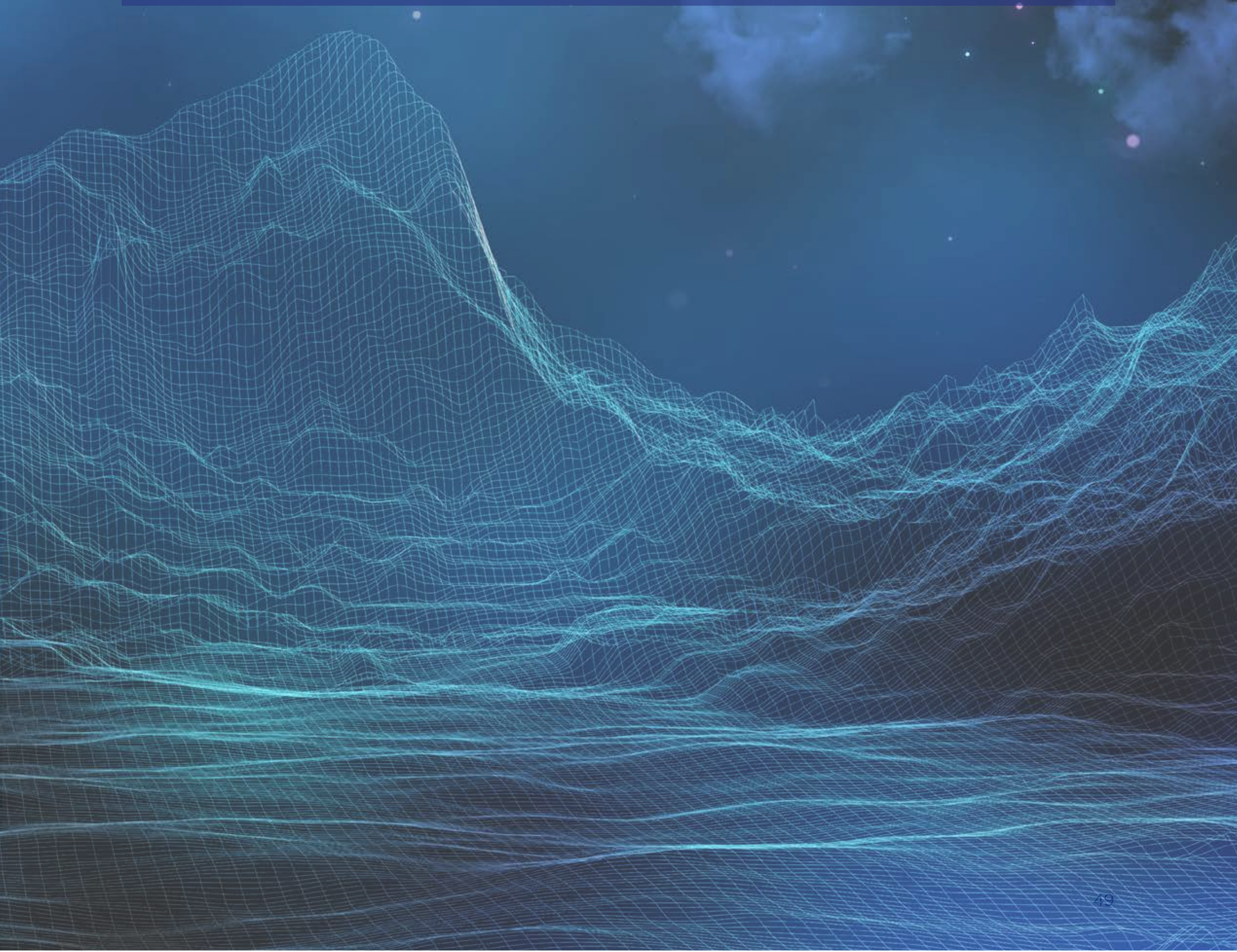
From the interview with Statkraft Peru we can conclude the following:

- Digitalization is seen as an improvement pathway for the company and it motivates the staff to keep improving the operation of the hydro power plants.

    - Peru has trained personnel to develop most of the digitalization tools needed

- Statkraft has a clear goal to digitalize most of what they operate to be competitive in the market.

6. FINANCIAL AND ECONOMIC ASPECTS OF DIGITALIZATION FOR A TYPICAL HYDROPOWER COMPANY

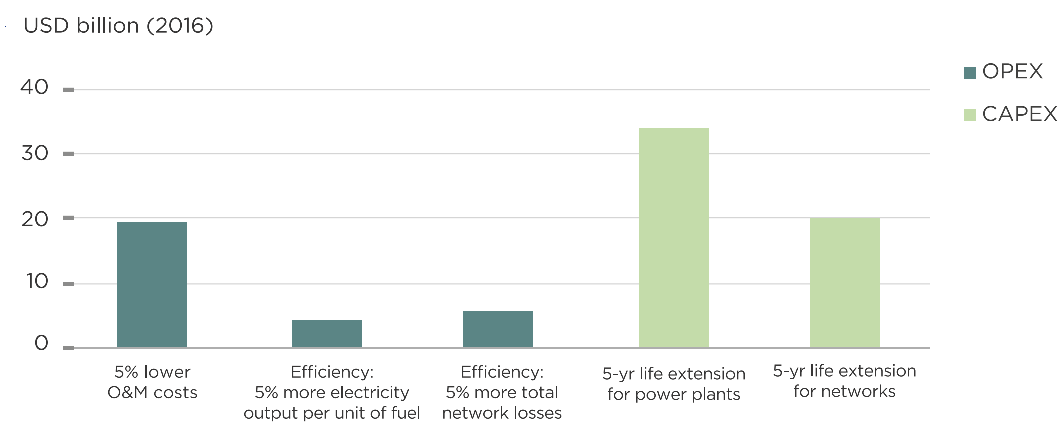


Digitalization can have many advantages in the daily business and operation of a plant, but one of the most important drivers is the financial benefit digitalization brings to the companies. Digital data management and analytics within the context of cost reduction can be seen in the following four fields:

- Reduction of the O&M costs;
- Optimizing the power plant and network efficiency
- Reduction of unplanned outages and downtime by the prediction of these, and
- The extension of the operational lifespan of the assets.

The IEA estimates that the overall cost reduction from these digitally enabled measures could be in the order of USD 80 billion per year over the period 2016-40, or about 5% of total annual power generation costs based on the enhanced global deployment of available digital technologies to all power plants and network infrastructure (see Figure 16). Although no estimation of the required investments in digitalization are provided by IEA, digitalization investments in general are low compared with their benefits, hence resulting in high cost effectiveness. Additional potential savings come from reduction of unplanned outages through better monitoring and predictive maintenance, as well as limiting the duration of downtime by rapidly identifying the point of failure. This reduces costs and increases the resilience and reliability of supply. Network failures are expensive, both for the utility and for the economy. For example, power supply interruptions in the United States alone have been estimated to cost around USD 100 billion per year. Emerging and developing economies generally suffer most from frequent power cuts[31].

Figure 16: Potential cost savings from digitalization in power plants and electricity networks over 2016-2040 - Source: Digitalization & Energy, International Energy Agency (IEA), 2018



Key message: Cumulative savings from the widespread use of digital data and analytics in power plants and electricity networks could average around USD 80 billion per year

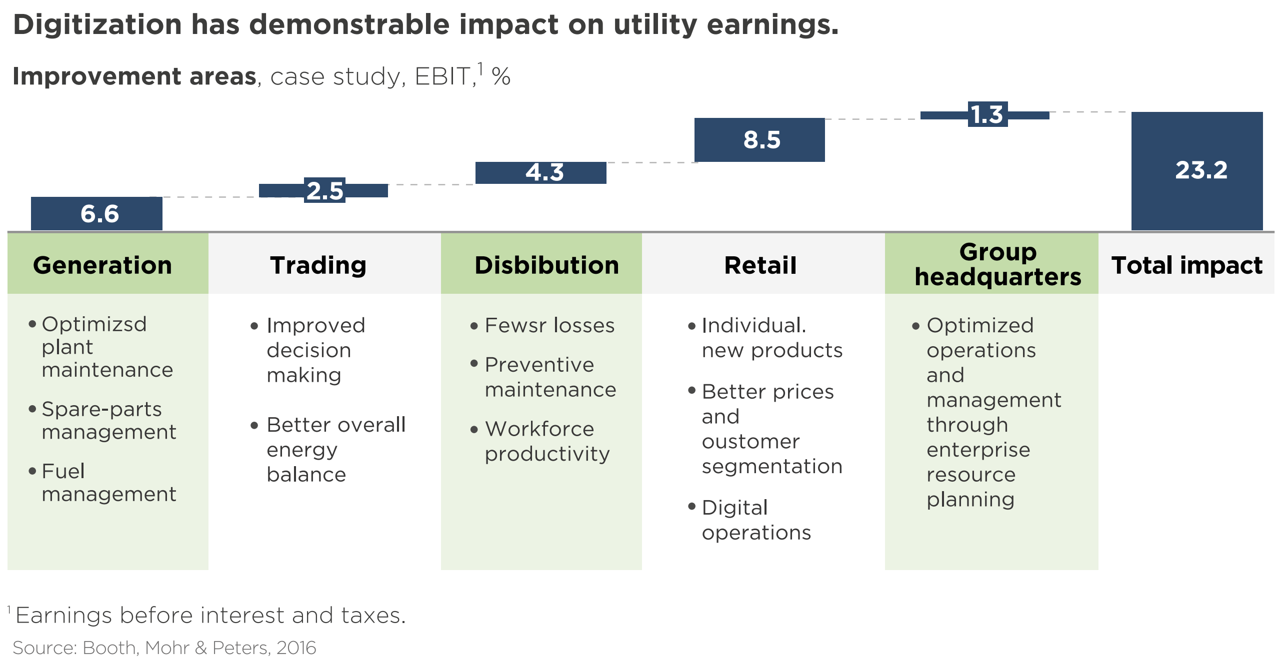
Notes: Assumes the enhanced global deploymente of existing digital technologies to all power plants and network infrastructure; CAPEX - capital expenditure; OPEX - operational expenditure; yr - year.

31. Digitalization & Energy, International Energy Agency (IEA), 2018

32. The digital utility: New opportunities and challenges, Booth, Mohr & Peters, 2016

Figure 17: Positive impacts of digitalization on utility earnings

Source: Booth, Mohr & Peters, 2016



Digital opportunities can be seen not only at the generation level but in the whole value chain. There conservative estimates that are supported by real data which suggest that digital technologies can improve profitability by 20 to 30 %. Of course, new technologies will keep appearing, but the objectives will stay the same. In generation, optimizing the plant's maintenance; in distribution, achieve fewer losses; among others.

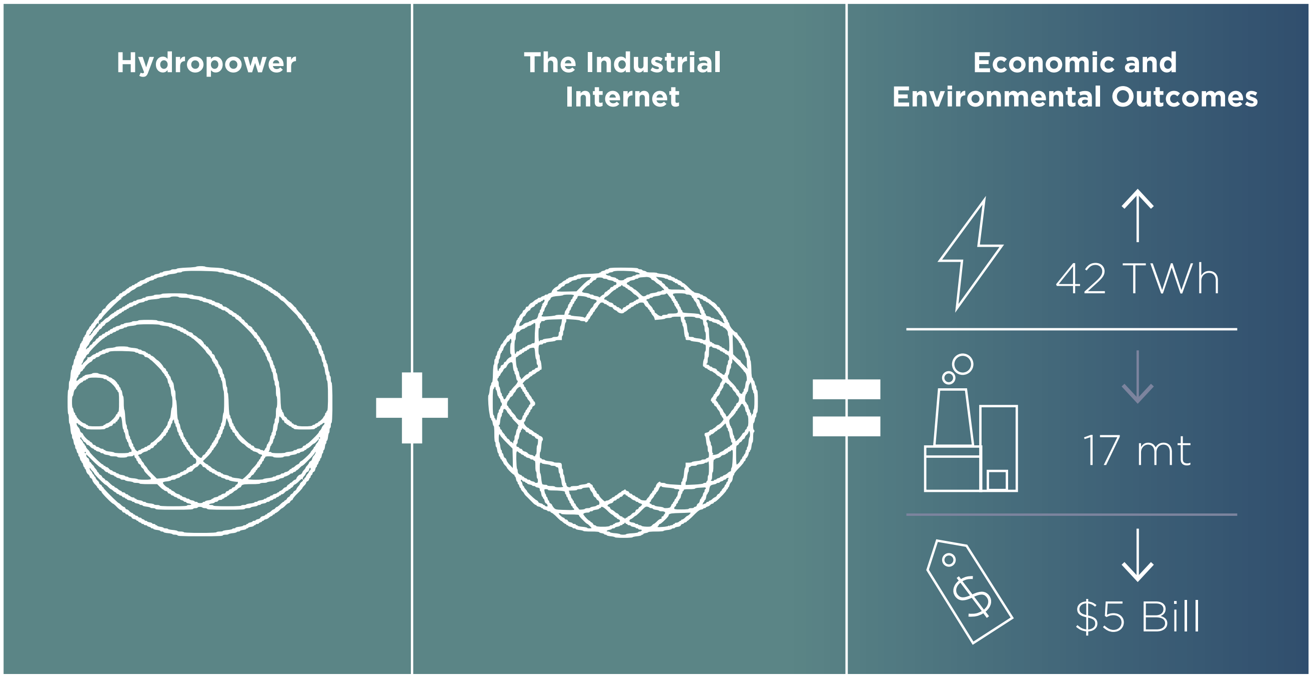
If we look at the hydroelectric industry and digitalized the world's 1,225 GW-worth of installed capacity according to a 2017 study performed by General Electric (GE) and IHA, this could equate to an increase of 42 TWh of incremental generation. This would be a USD5 billion operation saving per year and a reduction of 17 metric tons of carbon dioxide emission[33]. This saving is a global number due to all the digitalization tools but if we only look at a particular tool GE engineers indicate that intelligent condition-monitoring applications can saves up to USD 4,000 per MW per year in reduced maintenance costs, improve asset life and higher operation efficiency. GE indicates that their first customer of "digital hydropower plant" is experiencing reliability improvement of 1%[34]. Additional details of GE in executing digital solution for hydropower utilities around the world have been presented at the Salto Grande workshop on digitalization held on August 2018, and are shown in Figure 19. This Figure shows what challenges each company was trying to solve, which type of solution where implemented, and the outcomes that were obtained.

33. https://www.hydroworld.com/articles/hr/print/volume-37/issue-1/cover-story/smarter-hydro.html

34. https://www.ge.com/reports/dam-powerful-ge-connected-hydropower-internet/

Figure 18: Financial Aspects of Digitalization of Hydropower

Source: Hydropower's Digital Transformation, GE Renewable Energy July 2017



These digital applications obviously implicate investment, but every solution or tool has a different cost depending on the magnitude. For example, using a 3D printer to create a mechanical arm so that the technicians of the powerhouse don't have to risk their safety on standard procedures is around USD 300-4,000. In another case, Enel Green Power in 2016 launched a project called Big Data Hydro of an investment of 2.5 million euro for an initiative that aims to improve and maximize EGP's entire hydroelectric fleet by optimizing the operation and also by the identification of early potential malfunctions through the use of statistical analysis. As indicated in the previous chapters most LAC hydropower generators are already implementing some kind of digitalization tool. Nevertheless, up to now no consolidated number with respect of costs and savings can be given as different business areas in the same company are implementing different initiatives at the same time and long-term experiences are still missing.

35. https://www.enelgreenpower.com/stories/a/2017/09/the-future-of-hydroelectric-is-digital-

Figure 19: Challenges, digital solutions and outcomes of hydropower plants

Source: Digital Innovation for the Hydropower generation market by GE Renewable Energy Hydro, 2018

	BC Hydro	EDSB	EDP
Challenge	• *Aging hydro power plants approaching end of life - limits on CAPEX to replace and refurbish* • *New way to operate plants as peaking plants and as synchronous condenser capacities* • *Knowledge transfer issues (workforce made of very senior and veryjunior engineers, few middle-aged workforce)*	• *Extend TBO, reduce Mean Time To Repair (MTTR)* • *Accurately determine severity of heated bearings remotely* • *Transforming baseload operations to flexible*	• *Improve use & performance of critical power assets safely and without degrading forced outage rate (EFOR)* • *Improve operational efficiency* • *Break company silos by sharing real-time data on power gen assets across Operations, Maintenance & Trading EDP teams* • *Build a multi-fleetwide remote monitoring center*
Solution	• *APM Cloud Reliability Management deployed on HPPs over 20MW- Track of changes in equipment condition -9,000 tags monitored wl 260 diagnostics - automatic priority escalation (5 to 1)* • *Help maintenance engineers at generating facilities optimize and plan pre ventative maintenance*	• *APM Machine & Equipment Health with remote, real time connectivity to GE Center at Grenoble, France* • *Data acquisition and processing system with 11 sensors and local 30 HM/ to process 2 TB data/month* • *Automated diagnostics, Useful Life prognostics , and Vib. monitoring*	• *RM Cloud Analytics deployment to 56 units (25 failure modes)* • *Edge Platform deployment to 28 critical units (21 failure modes)* • *Pilot for Asset Strategy Optimization (1 HPP)* • *Partial load Extension (5 units, Francis & Kaplan) with real time risk hillchart visualization*
Outcome	• *Early notification of catastrophic failures (USO 200k-1 M lyear)* • *Reduction of forced outages* • *Elevate level of knowledge about the plant equipment and its condition* • *Optimize maintenance activities (from time-based to condition based)* • *Efficiency gains*	• *Precise diagnostics of shaft radial displacement, no shock or rub; likely due to external parameters* • *Bearing declared safe; no inspection or machine stoppage • $ 5 k of production loss avoidance* • *$ 3.2 k of inspection cost avoidance* • *-1% more availability*	• *Reduce loss of production due to internal causes by 24%* • *Decrease preventi ve maintenance costs by 10%* • *Increase revenues from balancing services (grid or portfolio) by 2%*

7. MAIN BARRIERS AND CHALLENGES TO INCORPORATE DIGITALIZATION

7.1

BARRIERS AND CHALLENGES FOR DIGITALIZATION IN ENERGY SECTOR

The main barriers/challenges to incorporate digitalization can be classified as cultural aspects (and thus technology adoption rates); skill gaps; regulatory aspects; and security concerns.

Insufficient infrastructure

The main requirement for digitalization is the adequacy of the existing energy and/or IT infrastructure in the country. Lack of either would pose a major barrier.

Cost and technology availability

Since digitalization technologies are relatively new in most LAC countries in compare to Europe, US or China, technology availability and cost may hinder digita development.

Regulatory aspects

Current regulations may not allow implementation of the innovations/technologies. Furthermore, the design of the new regulations may also pose barriers to digital transformation of different type of generation, depending on uneven allocation of subsidies, poor design of markets not supporting flexibility sufficiently, etc.

Skill gaps

Fast pace of technological improvements requires improved level of IT knowledge and experience in particular, not only for the design and implementation of the digital technologies but also for operation of the assets and the organizations; and continuous improvement to keep up with the pace of digitalization.

Security concerns

Security of energy system and the asset of concern are of vital importance, as a cyber-attack may affect not only one or more plants but the entire country. Therefore, security concerns may be a barrier both at investor level and at governmental level.

Cultural aspects

Existing workforce are concerned or skeptical about digitalization for a variety of reasons; lack of understanding of what elements of digitalization are essential vs. non-essential, added value of digital controls and impacts on current staff. This institutional barrier will cause organizations to fall behind in the adoption of new technologies and could result in lost opportunities and inefficient operations.

7.2

BARRIERS AND CHALLENGES FOR DIGITALIZATION OF HYDRO POWER SECTOR

The cultural aspects, skill gaps and security concerns mentioned above apply equally to all types of generation. Regulatory aspects on the other hand vary slightly. As mentioned above, regulatory frameworks may pose barriers to the incorporation of innovative technologies. Furthermore, it was identified that the challenges and most important barriers for the implementation of digital technologies in hydropower in LAC are:

Cost and technology availability

- that the implemented technologies might not be suitable to the system or equipment of the hydropower plant and might be rapidly outdated due to the fast development and changes in digital tools,

- that the cost of implementation of new technologies or systems is too high or not well defined and therefore there exist an increased difficulty in the decision making towards the implementation of digital tools

- that the economics of incremental cost due to the implementation of digital tools are unfavorable

Regulatory aspects

For the hydro power sector poorly designed regulations on subsidies and flexibility may pose considerable challenge against digitalization, as:

- Non-conventional renewable energy investments are subsidized in a considerable number of countries, but frequently hydropower does not face the same level of support as technologies such as wind and solar. This would reduce the investors' appetite for focusing on hydro sector and thus investing on digitalization of hydro power plants.

- Hydro power is a major source of flexible generation, which means hydro power plant owners can earn significant revenues from flexibility. Regarding the positive impact of digitalization increasing the flexibility of the plant to optimize its operation with respect to weather and market conditions, investors would be keen on digital transformation. However, insufficient value for the flexibility of the hydropower, including (for example) the day-ahead, intraday and balancing markets; and market-based (or value-based) system/ancillary services, instead of ancillary services being provided free or at regulated (SRMC) tariffs under Grid Code obligations can pose barriers for further digitalization.

Insufficient infrastructure, skill gaps and security concerns

As mentioned in previous sections, LAC countries are developing their path to digitalization at different pace, main barriers for them in the hydropower sector has been identified as follows:

- Infrastructure development, since there are more implemented advances in software than in hardware and connectivity, the pace of digital infrastructure development is in general slow in compare to the rapid changing technology within a digital world. This is mainly influenced by bureaucracy and lack of flexibility to adapt processes especially within governmental institutions.

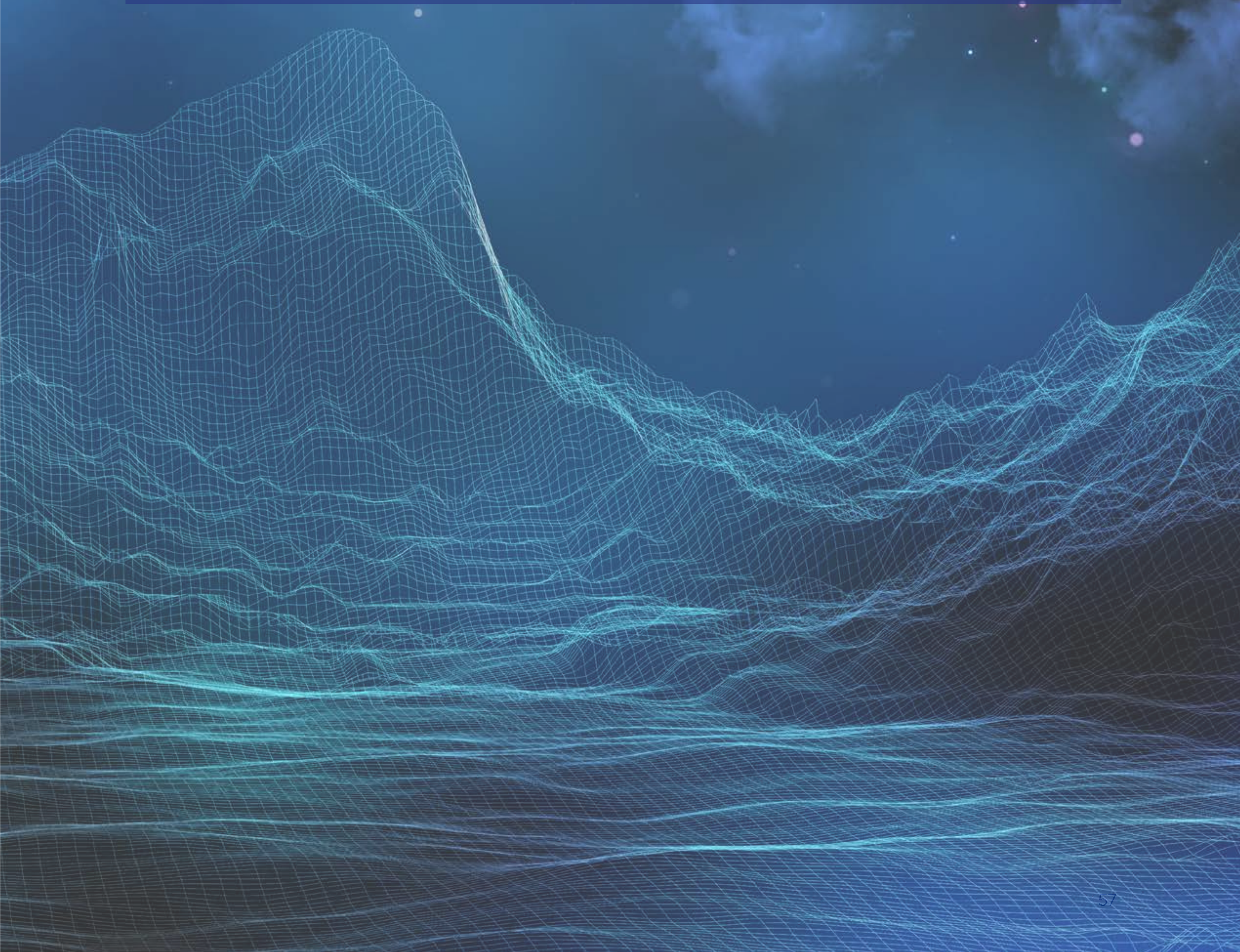
- Even though Chile is the most advanced country in terms of connectivity and the implementation of fully interconnected power plants also depends on public or general communications infrastructure where private companies cannot interfere and are bound to these conditions. As these plants often are in remote mountainous areas this can be a limiting factor for digitalization as cost can be out of economical boundaries.

- Cybersecurity: having a lack of skilled professionals.

- Access to skilled professionals due to lack of enough or adequate university curriculums → acquisition by importing/buying know-how from external/foreign providers.

- In compare to private utilities, mainly subsidiaries from global players in hydropower sector, digitalization for state companies would be constrained due to its limited budgets and lack of technology transfer as usually occurs in private companies.

8. ACTIONS TO TAKE TO MAXIMISE BENEFITS FROM DIGITALIZATION IN HYDROPOWER SECTOR



Based on the previous analysis, it is possible to identify some key actions that need to be implemented to maximize the benefits from digitalization. These are:

- i) removing (or at least mitigating) the barriers at national level, i.e. ensuring there is enough infrastructure; an efficient market design and a state-of-the art education system which can bring up professionals equipped with required skills; and

- ii) removing barriers at company level and ensuring digital readiness through an efficient change management.

- iii) create regulatory incentives to appropriately compensate hydropower for the additional ancillary and grid services that will be required with greater penetration of variable renewables.

8.1

REMOVING BARRIERS AT NATIONAL LEVEL

Infrastructure

In the last decades an increase in digital investments could be seen in LAC region. Nevertheless, to boost the digital economy and gain the benefits from digitalization more emphasis shall be taken to attract private capital throughout attractive tax saving business models.

Education

Although the education system in LAC countries is improving in regards to digitalization, great efforts are still needed at a national level in most of the countries, which are mainly linked to financial aspects.

If countries do not assign larger budgets for innovation and technology, it will be very difficult to break down the barriers into the digital world. This must be part of their education policy.

Efficient market design

As mentioned in Section 7.2, main barriers for digitalization in the hydro power sector are related to uneven subsidies and undervalued flexibility of hydropower. The solutions for these barriers would include:

- Multiple timeframe markets with balance responsibility for market participants
- Marginal imbalance pricing allowing for scarcity pricing
- Ensuring that there are proper provisions and value-based payments for system/ancillary services
- Ensuring that the renewable contracting/renewable support regimes don’t discriminate against hydro projects

8.2

REMOVING BARRIERS AT COMPANY LEVEL

A successful digital transformation requires actions on all company levels. Digitally oriented employees are just as necessary as the strong commitment from the management. This is the foundation for a cultural change program and an innovative mindset; it can be extended by training and hiring appropriate staff. On the operational level, business processes need to be adapted and digitalized, which requires an advanced and agile management due to the fast-changing challenges. Whilst strategies will differ amongst sectors and players, a few key components apply as follows:

[1]. Alignment – the digital strategy must align with the overall business strategy and strategic objectives.

[2]. Prioritization – companies must create evaluation criteria and adopt a "learn fast, fail fast" approach to ruthlessly select which projects to proceed with and which ones terminate.

[3]. Synergies – it is imperative to exploit synergies between initiatives by making sure they follow common protocols (e.g. in terms of data and platforms) so the initiatives can interact with one-another to create a suit that delivers more value than the sum of its individual parts.

[4]. Change management – this is about utilizing the power of digital to improve processes and change the way people work together; this means choosing the right operating model, recruiting people with the right skills, and ultimately instilling the right mindset and culture.

Some of the key considerations for project managers and decision-makers that came out of the IHA workshop (Bill Girling) included:

Engage senior management at an early stage

Almost all components of a hydropower plant will need replacement or upgrading at some point so, to retain an aging hydropower facility, modernization becomes unavoidable. Engagement with senior management at the earliest stage of modernization planning is essential to ensure that operational needs are recognized, and the risks and opportunities of digitalization are well understood.

Assess project cost-benefits and risk

Typically, modernization projects look to improve project performance, operating flexibility, competitiveness and risk management. The decision-making process on how and when to modernize is challenged in many organizations by limited capital, trade-offs against competing projects and 'urgent' maintenance needs. Digital decision-making tools such as digital twins can be utilized early on in this process to inform and optimize these decisions and reduce the financial risk of larger investments in modernization.

Consider staff resources and practices

It is important to consider not only the financial implications but also the potential impact of digitalization on a plant's human resources. In other words, how will the introduction of remote operations, digitalized monitoring systems and data analytics impact staff resources and working practices? Digitalization can provide an opportunity to reduce O&M staff costs, and at the same time new processes will require the retraining of existing staff to provide oversight or support and to ensure that skills are transferred from experienced operators.

Invest in skills development

Each digital system introduced to a hydropower plant involves training new or experienced hydropower operators and maintenance staff in new procedures for enhanced control systems, monitoring equipment, cyber-security, digital mapping and optimization software. Just as important however is retaining existing technical expertise on longstanding O&M procedures which will remain relevant as newer digital systems are implemented.

Understand digitalization at the policy level

The decision to modernize a plant can optimize the role hydropower will play in the future energy mix. It is important to engage policy-makers and regulatory authorities at the system and market level, recognizing that in many regions, a strategic plan will need to be developed for multiple hydropower plants, with the potential, in some cases of significant penetration of variable non-conventional renewable technologies such as wind and solar.

8.3

REMOVING BARRIERS AT REGULATORY LEVEL

Every new concept always brings uncertainty so being digitalization. Nevertheless, many companies, state entities and regulators around the world are investing heavily on developing new technologies and implementing the technologies that have been proven to work, yet in the LAC region this is happening at a slower pace.

There are several ways to boost digitalization in LAC and, according to Pöyry, the following can be mentioned with respect of removing barriers at regulatory level:

Building integral platforms:
As it is known, hydropower is not only contributing as renewable energy source but also enabling flood control, cleaning of the rivers, disaster management, leisure activities, irrigation and drinking water in multi-purpose schemes, etc. To boost digitalization in all these different sectors with different stakeholders a proven concept coming from Finland can be taken, where a platform was implemented allowing the creation of workgroups in different topics combing the know-how from the regulator, equipment providers, communication companies as well as scientific institutions as research centers and universities leading to "smart water" solutions which are backed up with up to date regulations and legalization eliminating barriers for implementing digital systems at the same time. At the same time this platform can work as knowledge transfer to the civil servants working in the different authorities and keeping them updated about the recent developments I digitalization.

Augmented flexibility in public tenders:
Digital developments are evolving rapidly and often procurement procedures coming from authorities with respect of public tendering are not flexible enough to allow the introduction of new digital systems which are developed during the time when terms of references are made public and the tendered works are finalized. In this context, more flexible tender procedures would allow and incentivize the participating bidding companies to implement state of the art technologies boosting the pace of digitalization in LAC in the hydropower sector.

Recognizing the value of hydropower: increased flexibility in operation due to implementation of digital technologies:
The value of the increased flexibility provided by hydropower plants is usually not recognized in most of the LAC markets, hydropower energy has to compete in the same terms with other forms of renewable energy such as wind and solar, although hydropower provides other systems services, such as frequency control, and long-term storage. In addition, hydropower plants coupled with digital solutions can promote further an efficient use of natural resources, as well as the reduction of climate gases, or even the increased efficiency of an entire generation system. For instance, by implementing flow forecast systems, based on intelligent system operation using big data and digital tools, the whole system operation can be improved. Therefore, the benefits provided by digitalized hydropower plants needs to be recognized, and the use of digital technologies needs to be promoted by modified regulations, incentivizing and/or rewarding the companies implementing digital technologies that might provide system-wide benefits.

Like these examples there could be a large number of ideas that can be developed by both public and private regulators so that the hydropower plants head towards the digitalization.

37. Finnish Water Forum http://www.finnishwaterforum.fi/wp/en/

9. CONCLUSIONS

Some key conclusions can be drawn from the discussion presented in this note.

First, from the perspective of hydropower development and digitalization:

- Hydropower will continue play an important role in energy generation in the next decades in LAC region. Therefore, adoption of digital technologies will bring new opportunities for its improvement in terms of decision-making processes to optimize cost operation, prevent outages and to refurbish and modernize old plants.

- Particularly, hydropower is an enabler for the deployment of non-conventional renewable generation, as it provides flexibility and storage capabilities. Digitalization of older hydropower plants will be necessary improve the operation of hydropower with other variable technologies, improving the system's security and efficiency.

- The range of application of digital technologies in the hydropower sector is wide, going across the whole hydropower plant lifecycle (planning & design, construction and the operation & maintenance) to meet high level objectives (safety, sustainability and commercial)

- In general, in the LAC region, main issue for hydropower digitalization is centralized operation through SCADA system – all further steps within the digital world still are ahead & might be implemented in the coming years. However, there are different utility operators (big players) going beyond SCADA driven by specific necessities without having in mind digitalization plans, which are coming further to stay competitive in the changing energy market.

Second, from the perspective of digitalization development in the region:

- Digitalization development in LAC countries is still behind Europe and US. As could be expected in such a diverse region, digitalization development is not homogenous. The leading countries in the region in this regard are Chile, Colombia, Argentina, Brazil and Costa Rica. Efforts must be increased, particularly in the countries that are lagging behind, as a digital gap is widening every year.

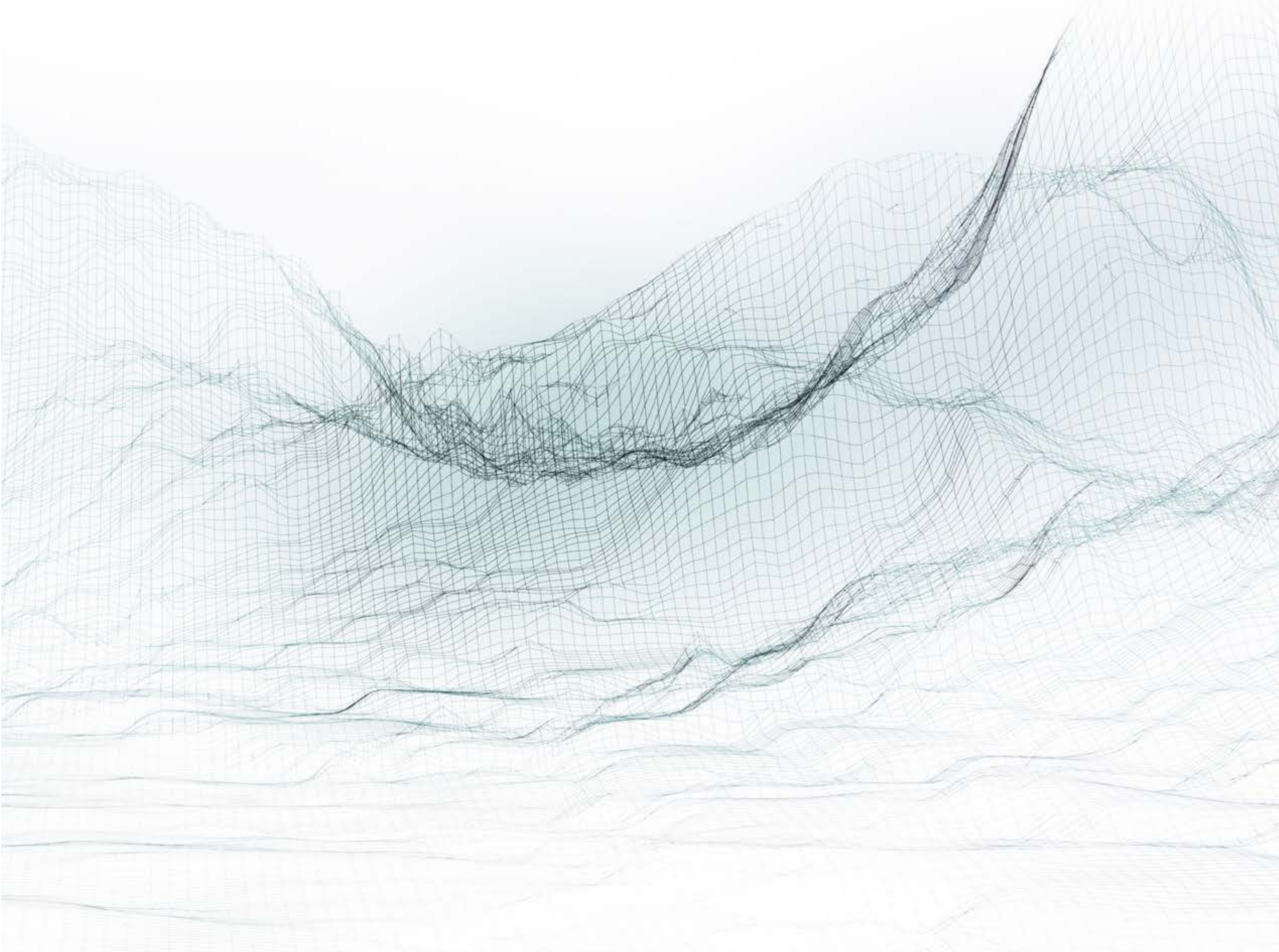
- Considering infrastructure, human capital and legal framework are the main factors for digital development, Chile is far leading the way to digitalization with the fastest progress on them and most countries within LAC region have to make great efforts to reach the fast-moving digital wave and its benefits.

- LAC region shows low levels of investment on innovation to promote digitalization at public and private levels. Due to the limited budget and the tendency towards bureaucratic processes at all state levels digitalization in most cases in the private sector is growing faster than that in public sector.

- Also, there exists cultural barriers for the development of digitalization. Existing workforce are concerned or skeptical about digitalization for a variety of reasons; lack of understanding of what elements of digitalization are essential vs. non-essential, added value of digital controls and impacts on current staff. This institutional barrier will cause organizations to fall behind in the adoption of new technologies, and technologies and could result in lost opportunities and inefficient operations.

In summary, digitization has become a powerful tool to improve decision – making processes in organizations that manage hydroelectric plants, helping to optimize water resource management. Digital technologies now have a wide range of application in all stages of hydroelectric projects, from design and construction, using digital simulation tools; to operation and maintenance, incorporating tools such as machine learning through remote monitoring of the condition of the assets. Digitalization of hydropower plants brings several benefits included increased efficiency, reduced costs, and improved security. These benefits are only for plant operators and owners, but also to the system operation, as hydropower can promote a more efficient use of all energy resources.

If the region wats to make the best use of its resources, reducing emissions and improving efficiency, digitalization of hydropower proves to be a part of the solution. Nonetheless, key barriers will need to be addressed, ranging from creating a "digital culture" in power companies, to improving the flexibility of bidding processes to enable the acquisition of innovative solutions. Importantly, new regulations can promote a wave of modernization in the power sector, by explicitly recognizing the value of digital solution and hydropower in the electricity markets.



ANNEXES

ANNEX I:

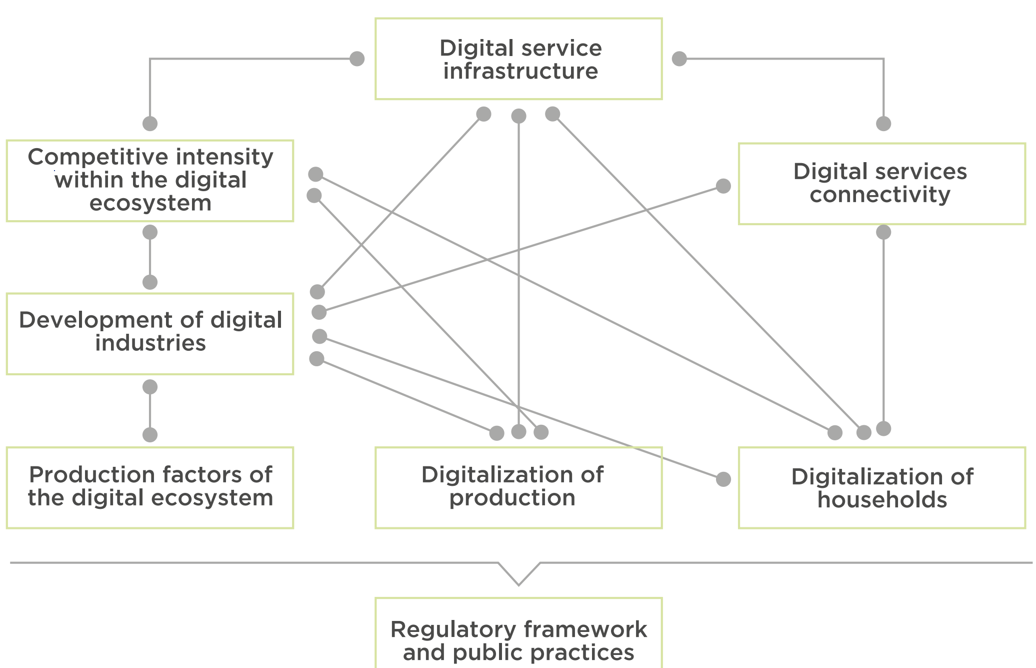
INDEX OF DIGITAL ECOSYSTEM DEVELOPMENT - DEVELOPMENT BANK OF LATIN AMERICA (CAF)

The index of digital ecosystem development developed by the CAF is calculated over an 11 year period (2004 to 2015) and combines 8 main patterns which consisting of:

- Digital service infrastructure: fixed and mobile telecommunication networks that transmit the data traffic that enables the digital ecosystem to function.
- Digital services connectivity: adoption of terminals (smart phones, computers) and services (fixed and mobile broadband) that allow access to digital transport infrastructure.
- Digitalization of households: use of Internet platforms and services by individual consumers (social networks, e-commerce, e-government).
- Digitalization of production: adoption of digital technologies by companies to increase their productivity and competitiveness.
- Development of digital industries: companies providing audio-visual content, social networks, search engines, telecommunications and manufacturing of equipment and terminals.
- Production factors of the digital ecosystem: human capital and investment needed for the development of digital industries.
- Competitive intensity within the digital ecosystem: industrial organization and concentration levels of the telecommunications markets, and Internet platforms.
- Regulatory framework & public policies

Figure 20: CAF index of digital ecosystem development LAC in 2015

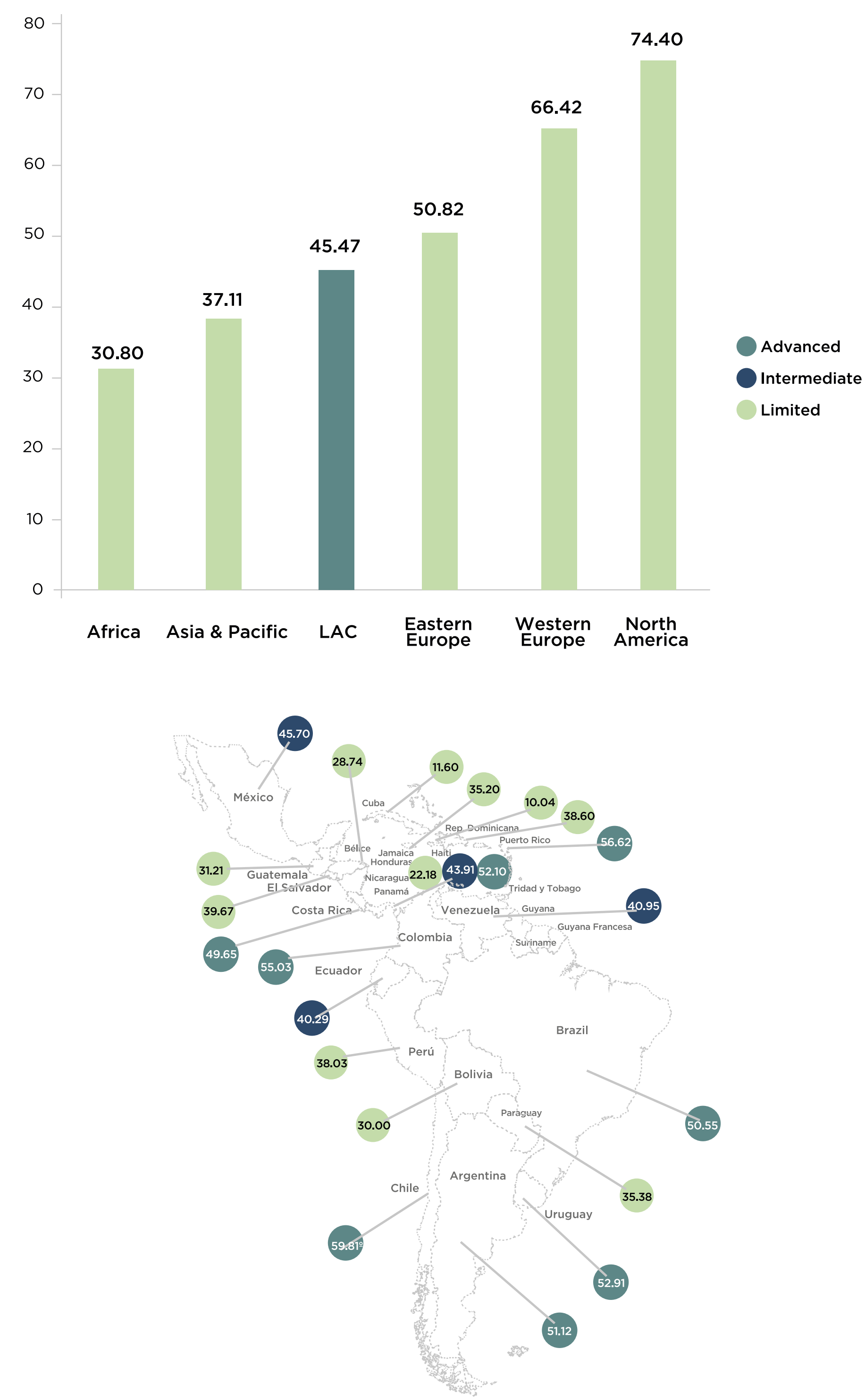
Source: IADB - https://cloud.mail.iadb.org/tramites#el-problema-con-los-tramites



The development across LAC countries is not homogenous. While Chile, Colombia, Argentina, Brazil and Costa Rica in 2015 had shown more advanced development, Peru, Paraguay and Bolivia were among the less advanced countries with limited digitalization development. (See Figure 21)

Figure 21: CAF index of digital ecosystem development LAC in 2015

Source: Hacia la transformación digital de América Latina y el Caribe: El Observatorio CAF del Ecosistema Digital (CAF, 2017)



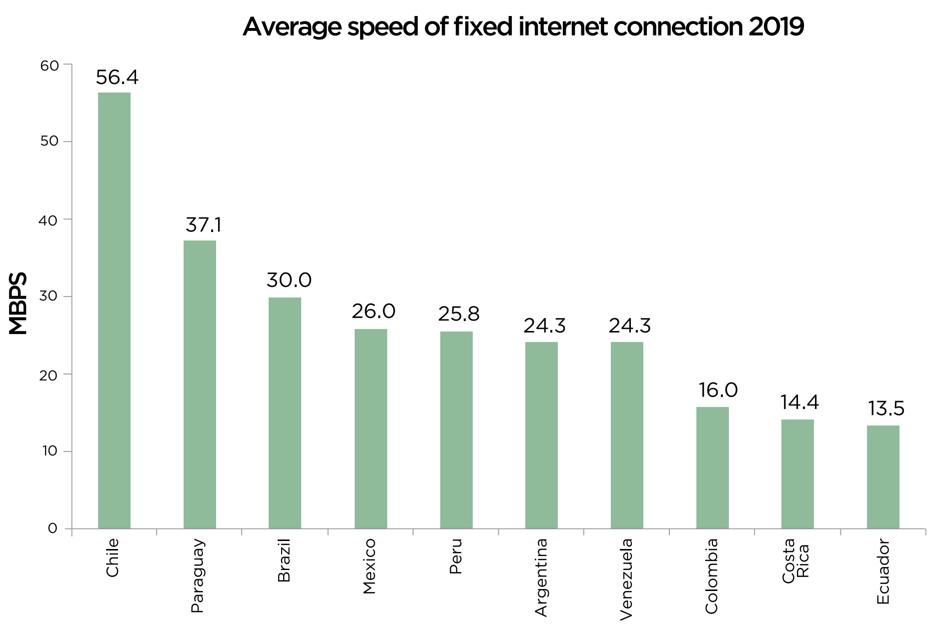
ANNEX II:

3 MAIN PILLARS OF DIGITALIZATION

There are many factor in regards the development of digitalization nevertheless there exist three (03) main factors which are:
Infrastructure

With respect to infrastructure, the most important variable is the available connection to the Internet (connectivity) as well as the supporting infrastructure consisting of fiber optic cables, servers up to satellite connections. Looking at actual data, Chile is far leading the implementation of high-speed internet connections, which is also responsible for its good performance in digital evolution. This item will be taken into consideration when discussing the digitalization in hydropower in LAC in the subsequent sections, as lack of infrastructure itself may be the basic reason for limited digitalization of the energy business.

Figure 22: Overview of average internet connection speed for selected countries (2019)
Source: DataReportal - https://datareportal.com/reports/digital-2019-global-digital-overview



Another important measure of good infrastructure is the ability of the utilities (or the government) to share real-time data on energy demand, supply and outages. The United Nations E-Government Survey 2018 shows that LAC is considerably behind Europe and North America in terms of sharing real-time data.

Human capital

Apart from the basic physical environment, human capital, which refers to the skill of workers to impulse digital transformation, innovation, patents and start-ups, subject to an adequate education, plays an important role in the context of digital evolution of the energy sector. In terms of education, LAC has had a significant improvement from 2004 to 2015 with a continuously growing number of university students in digital areas and increasing number of computers in schools per student. However, in terms of the percentage of GDP spent on R&D in LAC versus the Organization for Economic Cooperation and Development countries (OECD), LAC lies far behind with 0.69%, compared to 2.17 % in the OECD countries in 2015. Regarding careers that promote digital transformation like engineering, science and construction in LAC, only 943 of a total of 1,000,000 habitants are studying in these fields; whereas the numbers for Asia Pacific and OECD countries are almost three (3) times higher. Among LAC countries, only Chile and Colombia (almost) reach this level.

Institutional and regulatory framework

The institutional and regulatory frameworks are key factors that facilitate the development of the digital industries, as well as the promotion of connectivity. In terms of public and private investment to promote innovation, local production of innovation and economic development LAC region shows low levels . In general, digitalization in the private sector is growing faster than that in public sector due to the limited budget and mainly bureaucratic processes at all state levels .

ANNEX III:

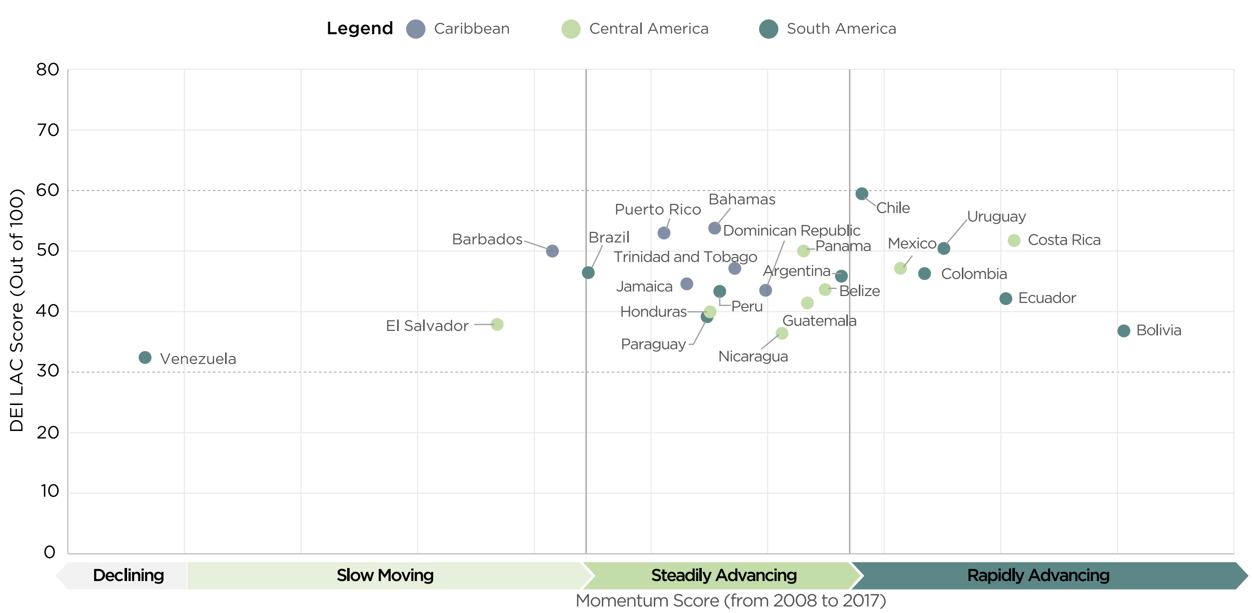
THE DIGITAL EVOLUTION INDEX:
LATIN AMERICA & CARIBBEAN EDITION (DEI LAC)

In general, there exist various indexes in recent digital publications. For instance, the “Digital Evolution Index: Latin America and Caribbean Edition (DEI LAC)” is a data-driven study of the pace of digital growth in 24 LAC countries across four key drivers of supply, demand, institutional environment and innovation. It utilizes 99 unique indicators measured over a ten-year period (2008 – 2017) to create an overall digital evolution score and digital momentum score .

According to the report, the region is experiencing a digital growth spurt. Nearly half of the 24 LAC markets included in the study demonstrate moderate momentum. A few countries are advancing rapidly: Chile, Costa Rica, Uruguay, Mexico and Colombia are leading the way, both in the state of digital evolution and their rate of progress i.e., digital momentum. While LAC has a tremendous potential for digital growth according to the CAF, it is in the middle band of digitalization globally. Governments and businesses need to do a lot more to advance LAC to the state and pace of global digital exemplars such as Estonia, Israel, New Zealand, and the UK, particularly in terms of improving digital infrastructure, fostering innovation, expanding digital and financial inclusion, and promoting digital economy friendly policies. There is a significant headroom for improvement in digital and financial inclusion. While access conditions have improved over the years, a large number of people in the region remain unconnected or under-connected, unbanked or under-banked. Over a third of the region is yet to experience the internet; women, young adults, and the poorest 40% in LAC are among the unbanked, according to the World Bank’s 2017 Global Findex survey. The DEI LAC demonstrates that LAC countries are at a crucial turning point – with the right mix of digital-first policy interventions, supply infrastructure stimuli, and a push to improve digital and financial inclusion, the region can unlock its true digital potential .

Figure 23: The Digital Evolution Index: Latin America & Caribbean Edition (DEI LAC)

Source: Digital Evolution Index: Latin America & Caribbean Edition, The Fletcher School, Tuft University, November 2018



ANNEX IV:

DIGITAL INITIATIVES IN DIFFERENT LAC COUNTRIES

Several digital initiatives are taking place in the LAC region mostly in the context of smart metering, energy efficiency as well as Smart Cities, as presented in Figure 24, representing positive examples for further investments in infrastructure, thus allowing further developments in the electricity generation market.

Figure 24: Digital Initiatives in different LAC countries

Source: Energy Markets in Latin America and the Caribbean: Emerging Disruptions and the Next frontier", World Bank, Washington, DC., 2017

Contry	Initiative
Argentina	**Buenos Aires' integrated response system** (Centro Unico de Coordinacion y Control, CUCC) coordinates and controls emergency response via an ICT platform (2011).
Brazil	**Rio Operations Center**, coordinates information and emergency response from multiple government agencies (2010). Several cities in Brazil use **advanced meter infrastructure (AMI) and efficient public street lighting** (LED luminaries). Electrobras has installed 100,000 smart electronic meters in Brasilia for the remote management of consumption and commercial losses. Several cities in Brazil use **advanced meter infrastructure (AMI) and efficient public street lighting** (LED luminaries). Electrobras has installed 100,000 smart electronic meters in Brasilia for the remote management of consumption and commercial losses.
Chile	**Energy Policy 2050** lays out specifics for the development of smart cities and establishes the Comuna Energetica program to help local communities explore the potential for energy efficiency, renewable energy, and sustainable consumption patterns. **Fundacion Pais Digital** coordinates between public and private actors to promote smart cities. Twenty-three municipalities are participating, some of which have already developed energy strategies and plans including renewable energy, energy efficiency initiatives and distributed solar PV. **Smart City Santiago** is an experimental laboratory in a business complex and residential buildings. **Smart City Gran Concepcion** is the first pilot of a comprehensive smart city model.
Colombia	**Medellin Smart City** brings together concepts of early warning emergency systems, sustainable transport systems, and ICT mplatforms to monitor public services and local environmental performance. **Bogota City** has begun an Integrated Public Transportation System that includes real-time data analysis systems.
Mexico	**National Air Quality Strategy (Vision 2017-2030)** includes among its various objectives two that are relevant to cities: i) achieve sustainable, resilient, inclusive and secure cities, and ii) gurantee access to affordable, reliable, modern, sustainable energy for all. **Mexico City Climate Action Program** establishes residential electricity and fuel consumption reduction targets and has a Green Plan that aims to allocate 8 percent of the city's annual budget to environmentally friendly initiatives. **Multiple Smart City Initiatives** have started in Puebla, Guadalajara, Queretaro, and Jalisco, some of which include smart energy grids, clean energy and distributed generation, promotion of sustainable mobility (bicycle corridors, carpooling), infrastructure for efficient water use, municipal geo-spatial data platforms, and energy efficiency in public buildings.

ANNEX V:

HYDROELECTRIC POWER IN LAC

When looking on the power mix of overall LAC, hydropower will certainly play the leading role in energy generation for the next 20 years counting with 71 % of relevance.

Figure 25: Generation technologies with mayor relevance on the electricity generation in 2040 in LAC (Survey from OLADE)

Source: Barómetro De La Energía De América Latina Y El Caribe 2018 Las Perspectivas Del Desarrollo Del Sector Energético En La Región Olade 2018

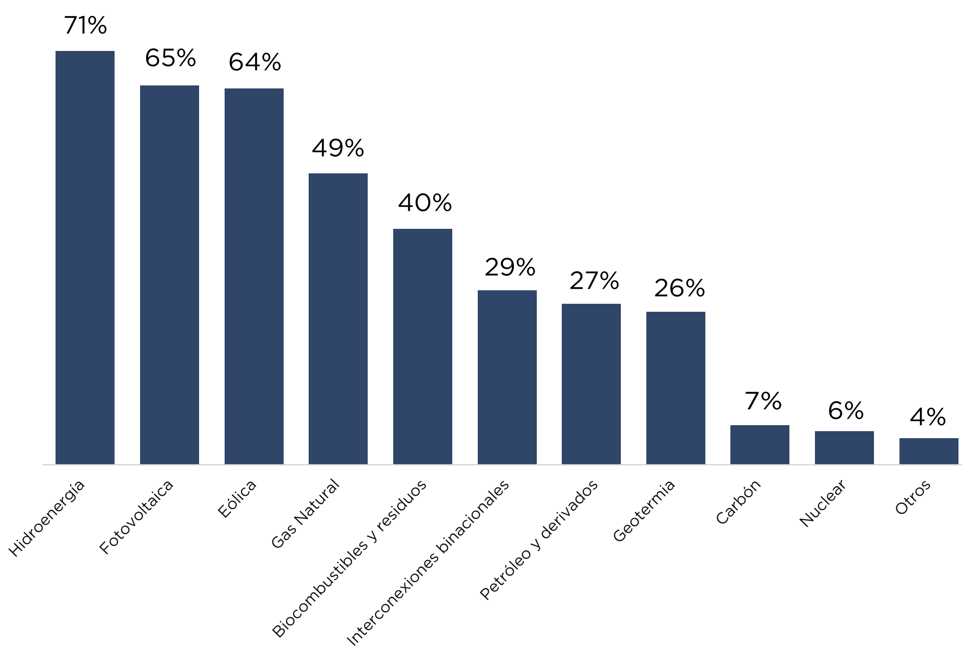


Table 1: Hydropower capacity in lac

HYDROPOWER CAPACITY IN LAC (MW)			
COUNTRY	**2015**	**2016**	**2017**
ARGENTINA	11,178.00	11,240.00	11,243.00
BARBADOS			
BELIZE	54.50	54.50	54.50
BOLIVIA	494.87	494.51	619.40
BRASIL	91,653.20	96,930.00	100,319.00
CHILE	6,523.10	6,657.96	6,669.38
COLOMBIA	11,500.55	11,606.40	11,725.63
COSTA RICA	1,941.70	2,328.05	2,328.11
CUBA	62.80	65.90	65.90
ECUADOR	2,407.61	4,446.36	4,515.96
EL SALVADOR	472.60	472.60	552.00
GRANEDA			
GUATEMALA	1,086.97	1,392.29	1,437.68
GUYANA			
HAITI	61.00	61.00	61.00
HONDURAS	631.70	670.40	675.80
JAMAICA	29.00	29.00	29.00
MÉXICO	12,489.00	12,589.00	12,642.00
NICARAGUA	137.60	142.45	142.45
PANAMÁ	1,726.00	1,768.70	1,777.30
PARAGUAY	8,810.00	8,810.00	8,810.00
PERÚ	4,151.84	5,189.25	5,245.93
REPÚBLICA DOMINICANA	617.13	617.25	617.38
SURINAME	189.00	189.00	189.00
TRINIDAD Y TOBAGO			
URUGUAY	1,538.00	1,538.00	1,538.00
VENEZUELA	15,136.81	15,136.81	15,136.81
TOTAL	**172,893.00**	**182,429.00**	**186,395.00**

ANNEX VI:

FINANCIAL AND ECONOMIC ASPECTS OF DIGITALIZATION

As stated in section 1.3 investments and the existence of adequate infrastructure are of crucial importance when talking about benefits from digitalization. The revision of CAF (2017) in terms of sales and export volume for different regions in the world, including LAC, clearly shows that LAC region performed quite well in the last decade. Nevertheless, LAC started at a rather low level compared to OECD, China and India and when looking on the direct comparison of sales and export volume the activities in LAC represents ~10 % compared to OECD. It is interesting to mention, that compared to China the volume of exported high-end services is about 50 % higher than for China although the export of high end products is only a quarter of the volume of China. This can be explained that in LAC there exist a rather well developed software industry supplied by hardware basically is manufactured in China; or in other words, that the digital industry in LAC is more focused on digital services than on manufacturing.

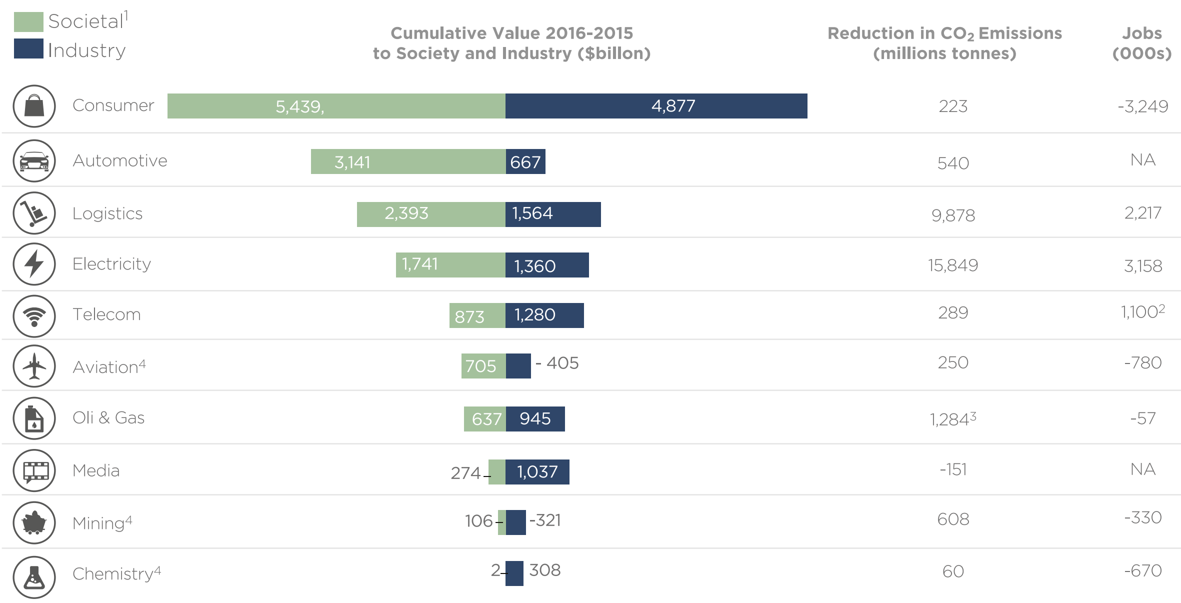
Table 2:
Source: Hacia la transformación digital de América Latina y el Caribe: El Observatorio CAF del Ecosistema Digital (CAF, 2017)

2004 to 2015	LAC	OECD	China	India	LAC to OECD 2015	LAC to China 2015
Sales in digital ecosystem	+ 136%	+ 22%	+ 157%	+ 127%	11%	79%
Export of high-end Products	+ 32%	+ 15%	+ 226%	+ 252%	11%	25%
Export of high-end Services	+ 336%	+ 111%	+ 237%	+ 269%	10%	152%

Looking at the outcomes from the world economic forum a distinctive economic framework helps business leaders, regulators and policy-makers to unlock an estimated $100 trillion of value that digitalization could generate over the next decade.
Figure 25 shows the expected value of digitalization for society and industry from 2016 – 2025. Accordingly, digitalization of electricity could unlock 3.1 trillion USD in industry and societal value over the next decade. Societal benefits stem from value creation for customers and a reduction in emissions.

Figure 26: Value of Digitalization for Society and Industry from 2016 – 2025

Source: World Economic Forum – Digital Transformation Initiative (May 2018)



Value creation across the industry and broader society will be driven by four major themes, namely Asset Life Cycle Management, Grid Optimization and Aggregation, Integrated Customer Services and Beyond the Electron (Hyper-personalized connected services go beyond the electricity value chain and adapt to the consumer). Following the outcomes of asset performance management will be the main contributor of digital benefits for the electricity industry. Furthermore, real-time demand platforms will contribute significantly for both society and industry in the next decade (see Figure 27).

Figure 27: Value at stake for industry and wider society, by digital initiative (cumulative 2016-2025)

Source: World Economic Forum – Digital Transformation Initiative (May 2018)